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ASTRONOMICAL RESEARCH IN INDIA: III

ASTRONOMY makes an instinctive appeal to all cultured persons. Of a different nature is the interest it has for the physicist. As indicated in an earlier article, the observational discoveries of astronomy have had a profound influence on physical thought. *Vice versa*, the speculatively-minded physicist turns naturally to the facts of astronomy to find in them a confirmation of his ideas or at least some support for them. This inter-play between astronomy and physics has been vastly more active during the last thirty years, since Niels Bohr put forward his Keplerian model of the hydrogen atom and offered an intelligible explanation of the observed spectra of both terrestrial and astronomical sources of light. The influence of Bohr's theory of atomic structure on astronomical and astrophysical research has indeed been no less remarkable than its influence on the sciences of physics and chemistry. The interpretation of the spectra of the sun, the stars, of the nebulæ, of inter-stellar clouds, and nearer to us, the spectra of the major planets and of the comets has been notably advanced and aided by the simultaneous advance in our knowledge of the structure of atoms and molecules and by laboratory investigations on the light emitted or absorbed by them under various conditions. The more recent advances in our knowledge of the structure of atomic nuclei and of their transmutations has similarly exercised a profound influence on speculative astronomy, and stimulated discussion on the internal constitution of the stars and the origin of the vast outpouring of energy from them which we witness daily. The work of the astronomical theorist on these problems has necessarily to be based on the results of terrestrial experimentation and on such inferences from them as are justified by established physical principles having the widest generality. Such work has a claim to acceptance which would not be extended to *ad hoc* hypotheses and speculations having no solid basis of experience behind them.

It is not surprising that the general advance of scientific activity in India during the past thirty years has been accompanied by an increased interest on the part of Indian physicists and mathematicians in the problems of astronomy, astrophysics and cosmology. The contributions by them to these sciences have not passed unheeded by the professional astronomers in other countries. Indeed, it may be claimed without exaggeration that the influence of Indian work in this field has been surprisingly great in proportion either to its volume or the actual effort put into it.

Astronomy, however, like all other sciences, depends for her progress mainly on the work of those who have devoted their lives exclusively to her service. Surveying the contribution of India to astronomy during recent years, one of its most heartening features is the work done by the Nizamiah Observatory at Hyderabad (Dn.) under its present Director, Rao Saheb T. P. Bhaskara Sastri. The equipment of this Observatory is comparatively modest and consists principally of an eight-inch photographic telescope and a fifteen-inch visual instrument. This equipment has been used mainly for co-operating in the great international undertaking known as the "Carte du Ceil" which

consists in making a detailed photographic survey and chart of the stellar universe. Regular observations of the variable stars is also part of the programme of the Nizamiah Observatory. The reports of the International Astronomical Union bear testimony to the speed and thoroughness with which the undertaking has been carried forward. The twelve volumes of the *Hyderabad Astrographic Catalogue* published by the Observatory form an impressive record of its work. Numerous short papers arising out of the variable star observations have also appeared in the scientific periodicals.

Though not actually "made in India", the work of S. Chandrasekhar, now Professor of Astrophysics at Chicago University, has a claim to notice in an article on astronomical research in India, if only as an indication of what could be accomplished in this country under favourable conditions. It would require an entire number of *Current Science* and not a paragraph or two to sketch the many fields of astronomical and astrophysical research traversed by Chandrasekhar and the results obtained by him during the last fifteen years. The *Monthly Notices* of the Royal Astronomical Society during the years Chandrasekhar was at Cambridge, and the last ten volumes of the *Astrophysical Journal* since he went to the United States bear witness to his energy, the strength and range of his scientific interests and his powers of investigation and exposition. His two treatises on "Stellar Structure" and "Dynamics of Stellar Systems" published by the Chicago University Press make his work in the respective fields conveniently accessible to specialist and non-specialist alike. A memoir on "Stochastic Problems in Physics and Astronomy" which appeared as the January 1943 issue of the *Reviews of Modern Physics* establishes links between the problems of stellar astronomy and those arising in colloid chemistry, and is a very remarkable effort in scientific synthesis.

In concluding this series of articles, the writer ventures to express the hope that they will not altogether fail to accomplish their purpose, namely that of impressing on all those interested in the scientific and cultural progress of India, the need for making generous provision for the promotion of astronomical study and research in our country, of encouraging those who are interested in the subject, and of making it possible for Indians working in their own country to contribute to its progress.

C. V. RAMAN.

SRI JAYACHAMARAJENDRA INSTITUTE OF INDIAN MEDICINE, BANGALORE

ON the occasion of the Laying of the Foundation Stone of Sri Jayachamarajendra Institute of Indian Medicine at Bangalore held on December 11, 1943, His Highness the Maharaja of Mysore declared:—

"I have watched with interest the researches made in this country from time to time in the indigenous systems of medicine. For want of facilities or due to other circumstances, they do not seem to have been conducted on modern recognised lines. It is only exhaustive investigation based on scientific methods in a well-equipped laboratory that will help the achievement of definite results of permanent value.

The rapid spread of education and the introduction of the more scientific and systematic methods of allopathy have led to the neglect of our ancient Ayurvedic and Unani systems of medicine. No one can deny that many indigenous drugs and medicinal preparations are potent and valuable. But the days of blind belief in the authority of the written word are gone and any system of medicine must stand scrutiny by the searching eye of accurate observation and experiment. A careful and assiduous application of modern scientific methods of chemical and biochemical research into the actions and uses of our indigenous drugs can alone convince a thinking public. I am, therefore, glad to note that the aim and object of this Institution is not merely to train pupils in the art of preparing and modes of using the medicinal preparations for which Ayurveda and Unani are noted. It will be a centre for organized research, on modern scientific lines, into the actions and uses of our indigenous drugs and herbs.

The advent of allopathy has made it imperative to import from foreign countries large quantities of drugs and medicines, many of which are expensive. I hope that every attempt will be made, by diligent research in this Institution, to find out simple and inexpensive substitutes which will be within the reach of even the poorest class of patients.

It has been said that no two practitioners of Ayurvedic or Unani prepare their medicines according to the same formula. There is great scope for improvement in this respect; and *the standardization of indigenous medicines* may very well be another object deserving of consideration in this Institute.

I should like to see greater *mutual understanding, a spirit of give and take, and more co-operation between the practitioners of indigenous systems and allopathy.* After all, where a patient's ailment is concerned, it is his speedy recovery and restoration to good health that counts, and not the particular method of treatment adopted, and faith plays no small part in the process of healing. This Institution, I expect, will be a meeting place for all practitioners—indigenous and allopathic alike."

SCIENCE AND THE PUBLIC WELFARE

By Prof. A. V. HILL, F.R.S.

WE'VE long felt in England that there's a vacant chair in the Councils of the allied scientists now meeting together in the West—for consultation, co-operation and research in connection with the war and for the reconstruction which will follow some day. That chair belongs to Indian scientists and we want them to come and fill it. I've said so myself a good many times. For some curious reason which I can't understand, because I'd never taken part in politics before, I became a member of Parliament in 1940, for Cambridge University: and in the very first speech I made in the House—I confess I was very frightened—I said in a debate on India that if by some chance my voice were heard there I hoped it might help a little to make people realise that however difficult in some fields co-operation might be, in the scientific field it was easy, practical and of great importance for our common welfare.

That was three and a half years ago and I've gone on saying it since, and others have said it; and in the last few years we've elected four distinguished Indian scientists as Fellows of the Royal Society—which *some* people feel is the greatest honour any one can have next to the V.C.! Now it is an old dodge, when some one makes himself a nuisance by going on saying that something ought to be done, to reply "well, do it yourself", and to appoint him chairman of a committee to consider the matter. That usually disposes of him and his complaint for good. This isn't exactly what happened, but in the end the Royal Society sent me as its representative to India to look into scientific matters here, particularly in relation to co-operation between Indian Science and the rest of us. Whether people thought that would dispose of me I don't know—I don't think so, judging from the extreme friendliness with which I have been received here—but if they did they are quite mistaken—I'm not a bit disposed of, and intend to go on saying the same thing louder and louder until every one gets thoroughly tired of it.

The full title of the Royal Society—which was founded in 1662—is the Royal Society of London for Improving Natural Knowledge. Its cousin in Philadelphia, founded by Benjamin Franklin in 1743, is called the American Philosophical Society for improving *useful* knowledge. Notice the difference between English and American—we knew that natural knowledge was useful but didn't say so, and they did. The Royal Society has a Royal Charter given to it 281 years ago. It's entirely independent of the Government, but all through its long history it has co-operated with the Government in a number of scientific and practical questions, for example, in the voyages of discovery of Captain Cook, in the work of the War Food Committee in the last War, in directing the work of the National Physical Laboratory, and in 1939 in constructing the Central Register of Scientific Personnel for the Ministry of Labour. More recently still the War Cabinet Scientific Advisory Committee was set up under the Lord President of the Council, consisting of the three principal officers of the Royal Society and the three principal scientific officials of the Government. In all this friendly and familiar co-operation between an entirely independent body and the Government you have a typical example of an essential principle in our British organisation—which other people, if I may say so humbly, might be wise to copy—the deliberate reconciliation of order with freedom. I hope it may not be long before a single Indian scientific body crystallises out, as an opposite number of the Royal Society, with similar functions and influence, a similar independence and a similar Charter from the Government. I think I can say that when it does the Royal Society will be proud and happy to enter into the same friendly and familiar co-operative relations with it as it has already with the National Academy of Science at Washington and with other similar bodies.

The first Indian Fellow of the Royal Society was elected 102 years ago. The latest, Sir Shanti Swarup Bhatnagar,—my friend Dr. Bhatnagar was elected this year. The four who have been elected lately have been unable—owing to the war—to attend in London for their formal admission to the Society. The President has asked me, while I'm in India, to act on his behalf and to take a suitable occasion of admitting these gentlemen to the Society; and of getting them to sign their names on a sheet of parchment which will later be inserted in the Charter Book in which all our Fellows have signed their names ever since 1662. This duty I hope to be able to perform at the meeting of the Indian Science Congress in January and His Excellency the Viceroy, whose grandfather and great-grandfather themselves were Fellows of the Society, has promised to attend. And on that occasion I hope to give the Indian Science Congress messages of greeting from Sir Henry Dale, the President of the Royal Society, from Sir Richard Gregory, the President of the British Association, and from two other famous Fellows of the Royal Society, *viz.*, Field-Marshal Smuts, and Mr. Winston Churchill, whose ancestor—Sir Winston Churchill—the father of the great Duke of Marlborough, was himself one of the first Fellows of the Society.

I've talked rather a lot about the Royal Society, partly because I'm here as its representative, partly because I've no time to go into details and want to talk about principles. And the fundamental principle of all good Government, as I see it, is the friendly and familiar co-operation of independent institutions and people of good-will with Government—for advice, for criticism when necessary, for co-operation. We must expect, in the present development of the world, a great growth of Government machinery: and a bureaucracy is bound to become sticky, sterile, overbearing

and inefficient unless it continually tries—or is forced—to meet healthy independent opinion. In scientific matters the Royal Society is typical in Britain of that healthy independent opinion. Moreover, if the Governments of different countries are to work with one another—as they must if the world is not to remain chaotic—they can best learn to do it, not directly, but through the familiar contact of their independent citizens with one another. The fact that the Governments of Great Britain, U.S.A., and the Dominions are now collaborating so efficiently in scientific research and technical development in connection with the war is not due simply to their own good sense, but because the scientists and engineers of these countries knew each other so well that they forced collaboration on their Governments. The scientists of all the United Nations are working together now with a degree of unanimity and good-will which is due, partly indeed to a common cause, but at least equally to the fact that such collaboration is a common tradition of science, the tradition of many centuries of experience and good fellowship. That tradition will continue anyhow and we may hope that a common cause will remain too, after the war's over. That common cause will be the improvement of human welfare, in knowledge, health, agriculture, nutrition, industry, communications, education,—and freedom from want, sickness, ignorance and fear.

All this common machinery of scientific research and development which we've created for the war, both for defence and offence and for maintaining a stable base of health and welfare at home, must not end suddenly when the war's won but must be carried over gradually to deal with the problems of individual, national and international reconstruction; and then—when that's complete, if it ever is—for human betterment on an international scale.

If any one dares to say that all this will cost too much, we must insist that the cheapest and most certain method of human betterment is the improvement, in Benjamin Franklin's words, of useful knowledge. If a country's poor and undeveloped let us spend *more* on research not less: the amount we can possibly spend is insignificant—only 1 or 2 per cent. of the national income anyhow—and will bring a very handsome dividend. As Herbert Agar says this is a time for greatness—we must either be great or dead—and one important element of greatness is intelligence. Stupidity and ignorance are not campatible with greatness.

In what ways can science help us directly in promoting human betterment? In England now we are contemplating a vast expenditure on housing, in the next twenty years, £2,000 million or 2,600 crores of rupees. One per cent. of that spent on research, on design, materials, building, heating, lighting, ventilation and amenities, will certainly make the new houses many times one per cent. better, healthier and more efficient. We are, in fact, already devoting whatever effort we can spare from the war to research on building. We mine 20 crores of tons of coal annually—1 per cent. of its cost spent every year on research will certainly improve the efficiency of its utilisation by many times 1 per cent.; we're intending to spend half at least of that by a joint co-operative effort between Government and the industry. There are 60 million people in the Colonial Empire. The Colonial Research Committee, under the Chairmanship of Lord Hailey, is able to spend £500,000 or 6½ million rupees annually of Government money as soon as research workers are free from their war duties. Its purpose is by research to improve the welfare of the Colonial peoples. It sounds a lot but it only comes to one or two annas a head. Your Department of Scientific and Industrial Research is allowed to spend 10 lakhs of rupees per annum. It's doing very fine work for your country, as I've seen already for myself, but the cost is only 1/25th of an anna for each inhabitant of India. It could usefully spend ten times as much. Your annual budget now I'm told is 600 crores of rupees; 1 per cent. of that's 6 crores. My scientific friends in India would be very happy indeed if they could look forward to anything like that. In England I suppose we spend £50 million a year on medical treatment and to this might be added several times the amount for time and health wasted owing to preventable disease. Medical research in all its forms does not spend more than 1 per cent. of that. The Industrial Research Associations in England spent in 1938 about half a million pounds—a very small fraction of 1 per cent. of the annual value of British industrial production. I want my listeners to get one very simple idea into their heads—1 per cent. It does'nt sound very much. Let us aim at giving 1 per cent. of our national budget, 1 per cent. of the value of our industrial and agricultural production, 1 per cent. of the loss due to ill-health, 1 per cent. of the cost of our food, our transport, our houses, our water, our coal, even our broadcasting, to research—and in ten years we shall find that we're getting back not 1 per cent., but 10 or 20 or 40 or 200 per cent. in dividends. During the last War there was a picture in *"Punch"* showing the proprietor of a sweet shop changing the label of his Turkish Delight to British Delight. It was called 'Honesty is the best policy'. Research is like honesty—the best policy.

You'll see that I pitch my claims high, but I'm *not* selling you a nostrum. If the history of modern industrial development had taught us nothing at all, the history of the present war would have taught us that to neglect research is to invite calamity. The Battle of Britain depended on the courage and skill of a few brave young men in Hurricanes and Spitfires—but it depended also on the knowledge and skill of a few young scientists sitting behind cathode-ray tubes. The battle of the Atlantic has depended on the courage and skill of sailors and airmen, but it has depended also on the scientists and engineers who devised and used the means of intercepting the U-boats and confounding their devices. The fact that in spite of our hardships the health and good humour of the people in Britain is at least as high as in ordinary times has depended on vigorous administrative action based on

knowledge of nutrition, health and even applied psychology. So, in days to come, the reconstruction of Britain, Europe and the world will depend on courageous and far-sighted planning based on science applied to industry by co-operative effort, to health, to agriculture, to transport, housing, raw materials and a proper survey of natural resources.

I cannot claim as yet to have much direct knowledge of Indian problems but it's clear to me that three of the greatest problems of India—really they make a single problem—are biological ones, those of agriculture, health and population. These all act and react on one another and they react with the other scientific and technical problems of industrialisation, transport, communications and—not least—education. We've failed too often in Europe to look at our problems objectively, and it has been too easy to get excited about political differences when fundamentally our real needs were common ones which we could have solved in co-operation. I should not dare, as a scientist, to intervene in Indian political problems, and our own behaviour in Europe does not entitle a European to point at our own history as a very good example. It should, however, be possible to learn from failure and disaster and our failure has been too often that we have refused to recognise our common needs because of political differences. "Perhaps in India you'll be able to profit by our mistakes. One piece of advice, however, I'm confident in giving, namely, that it's worthwhile devoting a greater fraction of your national effort to scientific research and technical development: and I'd like to leave you with the three words —'one per cent.'"

SOUVENIR TO THE HON'BLE DEWAN BAHADUR SIR A. RAMASWAMI MUDALIAR, K.C.S.I.

SIR ARDESHIR DALAL, presenting the *Souvenir* to Sir A. Ramaswami Mudaliar on behalf of the Board of Scientific and Industrial Research, said that the Council of Scientific and Industrial Research owed its existence to the wisdom and foresight of Sir A. Ramaswami Mudaliar who alone realised, when others were urging the abolition of the Board, war was not the right occasion when scientific research should be cut down. It was just the time when it should be expanded. It was the last war that made England and America realise their backwardness in the matter of scientific and industrial research. England found that many of the materials necessary for the carrying out of the war she was incapable of producing and she was considerably handicapped in her fight against Germany which had a perfected scientific research organisation. It was in those circumstances that the Department of Scientific and Industrial Research had come into existence as separate organisation in England and America. In India at that time people did not realise the position and it required constant urging from scientific bodies all over the country and the sympathetic response of the Member of Government like Sir A. Ramaswami Mudaliar to bring the Board of Scientific and Industrial Research into existence.

It was too early, continued Sir Ardeshir to assess the work of the Board. Like all other newly founded bodies the Council had its troubles; it committed mistakes; but he did not believe that even the most unfriendly of critics could say that it had not already to its credit substantial achievements. For his part he said he was amazed at the wealth of scientific talent which the creation of the Body had brought forth and he made bold to say that given necessary facilities and opportunities there was nothing which scientists in India could not accomplish which others had done.

Sir Ardeshir next pointed out that the Council had enabled industrialists and scientists to come together. It had removed mutual misunderstandings between them. As a result the scientists no longer regarded the industrialists as mere exploiters who were interested in scientists to the extent they were useful to them in their efforts at "Dollar-making". The industrialists no longer regarded the scientists as mere theorists devoid of all practical touch with the realities of life. If scientific and industrial research had not made the progress that was expected of it, the main handicap was want of adequate resources. The Board was indebted to Sir Ramaswami Mudaliar for the grant of Rs. 10 lakhs which he had made the Government of India give to them. But Rs. 10 lakhs was a mere drop in the ocean and it bore no comparison to the huge amounts expended by England and America on scientific research. Even one crore would be not a great sum, in relation to the National wealth of India.

Replying, Sir Ramaswami Mudaliar said:—"Whatever may happen in the next few years, whatever political conditions we may or may not have, however much there may be suspicion between communities in this country, the force of time and the trend of events are such that industrial development in this country is an assured fact. Let there be no doubt about that. In the next three or five years there will be more industrial development than there has been in the past thirty years."

Thanking the Board for the beautiful *Souvenir* they had presented him with Sir Ramaswami Mudaliar said, "Coming as it did from eminent scientists and great industrialists in the country, he would treasure it as a priceless heirloom".

Proceeding Sir Ramaswami Mudaliar said that he had always felt that his contribution towards scientific effort was a drop in the ocean when compared with the generous contribution that had come from hundreds of scientists throughout the country. Theirs had been a most ample and generous response. But their talents had not been adequately recognised in

the past. There was no lack of scientific knowledge in this country and if the industrialists and scientists could be brought together and the latter realised the full value of scientific research, the industrial problem of India would be solved in no time.

Whatever might be the case with other countries, continued Sir Ramaswami Mudaliar, we must adapt ourselves to conditions in this country and it would be a most profitable mixture or amalgam to bring industrialists and scientists together in this Body and it was in that belief that this Body had been constituted. As a result of such co-operation he hoped that the Board of Scientific and Industrial Research would grow from shape to shape and from strength to strength.

He assured the members of the Board that his whole heart was with them and that he would continue to do what all he could for that Body to establish itself on a sound and permanent basis.

THE CENTENARY OF THE ROTHAMSTED EXPERIMENTAL STATION

THIS year the Rothamsted Experimental Station, which is the oldest agricultural experiment station in the world celebrated its hundredth anniversary. Most people have heard or read of the Rothamsted Experiment Station; many have either studied at the Station or visited it; but very few know of the history of the origin and development of this well-known agricultural experiment station which has done so much for the development of scientific agriculture.

Rothamsted is a village near Harpenden in Hertfordshire in England and belonged to John Bennet Lawes, a young English squire, who took great interest in farming. Lawes was born in the year 1814. His favourite hobby as a boy was experiments in chemistry. At the early age of twenty years, Lawes took into his hands the management of his farm at Rothamsted. One of the first things he did was to convert one of the barns into a chemical laboratory. With his close association with the farm and its crops Lawes soon became interested in the study of the growth of plants and began pot experiments with different crops and manures. He found that plants grew well in pots that received an application of animal charcoal, which was a waste product. He further found that plants grew even better if, before application, the animal charcoal was treated with sulphuric acid. Lawes had the vision to see a good business proposition in the results of these experiments and set up a factory for the treatment of animal charcoal, bones and phosphatic minerals, with sulphuric acid, and the production of super-phosphate. Thus were laid the foundations for the artificial fertiliser industry, which in subsequent years developed to enormous dimensions.

In 1840, Liebig enunciated his new theory of plant nutrition. Lawes carefully studied the principles underlying the theory. He had already his own ideas about plant nutrition and was, therefore, not convinced that Liebig's theory was entirely sound. He found that while the theory was sound in principle it was faulty in detail. He wanted to test it and correct it and for doing so, he required the help of a trained chemist. He engaged Joseph Henry Gilbert. The two worked together for nearly sixty years and laid the foundations not only of the Rothamsted Experiment Station but of agricultural science also.

It was in 1843 that Lawes and Gilbert laid at Rothamsted the first set of field experiments which were destined to become classical and which happily continue to this day. The Centenary of Rothamsted is thus really the centenary of these classical field experiment plots. The two young scientists could not possibly imagine then, that their experimental plots would be continued. If now they could come to life and visit their experimental plots at Rothamsted and the several hundreds of such plots since laid all over the world they would nod their warm approval with justifiable pride. Few partnerships in the field of science continued so long and with such fruitful results.

A few years before his death in 1900 Lawes established a trust under the name of Lawes Agricultural Trust and endowed it with £100,000 so that the great work which he initiated might be continued. He had the vision to realise that work must progress in consonance with the advance of science in the future and made the terms of the trust sufficiently wide to prevent unnecessary limitations. And what is more, he allowed for one hundred years the use of an area of over fifty acres for the continuance of his classical experiments.

After the death of Lawes in August 1900 A. D. Hall (later Sir Daniel Hall) became the first Director in 1902. Hall started his career as a lecturer on matters of interest to farmers, and before he became the Director of the Rothamsted Experimental Station was the Principal of the College of Agriculture at Wye. He collated the results of the experiments of Lawes and Gilbert, and wrote a book which is full of interesting and instructive tables besides a good deal of other useful information. Hall was succeeded by Dr. E. J. Russell (now Sir John Russell) as Director in the year 1912 and his retirement after thirty-one years as the Director coincides with the celebration of the Centenary. Dr. Ogg has now succeeded Dr. Russell as the Director of the Rothamsted Experimental Station.

When Lawes and Gilbert began their experiments chemistry appeared to be the only science that had a bearing on agriculture and for a long time that was the only science used at Rothamsted. Hall realised that chemistry and fertilisers were not the only ones that mattered and that other sciences were equally

important in agriculture and invoked the aid of botany, physics, microbiology, organic chemistry, entomology and plant pathology, in the study of problems concerned with soil conditions and plant growth. The development of biological research required mathematical methods for the sifting and evaluation of experimental data, and this need has been met by the addition of a section of statistics.

Since the time of director Hall and during the time of director Russell the Rothamsted Experimental Station marched from progress to progress and to-day the Station is well equipped for research on all problems in soil management and crop production. The work is carried out in a number of sections and subsections dealing with botany, soil physics, soil chemistry, microbiology, field experiments, statistics, crop physiology, insect pests, and plant diseases. The contributions of these different sections to the science and practice of agriculture are great and enduring.

The fields of work initiated at Rothamsted a hundred years ago by Lawes and Gilbert and subsequently developed by those that followed them are still yielding rich harvests. The founders started their programme of work on fundamental scientific problems. They did not base their programme of work to deal with the then problems of immediate practical importance even though that would have been justifiable in those difficult days called "the hungry forties" when more and cheap food was in great demand. Had they done so we would not have to-day the results which are so widely beneficial and permanent in value. Lawes and Gilbert laid emphasis on gaining knowledge as they had the vision and insight to realise that knowledge is essential for advance. The world to-day cannot be too grateful to these pioneers. Rothamsted celebrated its Centenary by extending the laboratories and facilities for scientific work and that is a fitting and enduring expression of gratitude to the great founders of the Rothamsted Experimental Station a hundred years ago.

B. VISWA NATH.

STUDIES ON THE PRESERVATION OF GLANDS
II. Preservation of Pituitary Glands

BY
B. B. DEY, P. S. KRISHNAN AND M. GIRIRAJ
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ADRENALINE AND THYROXINE are typical examples of hormones which can be isolated in pure crystalline condition and which can, therefore, be correctly dosed in the preparation of injectules. The posterior pituitary, on the other hand, is very often administered as a crude extract ('Pituitrin'), which is prepared by extracting the desiccated powder with 0·25 per cent. acetic acid and then distributed into ampoules after bioassay, such that each c.c. contains ten international units. Any decrease in the potency of the powder would necessitate more of powder to be extracted to give the same volume of solution: this would naturally involve the presence of more of extraneous protein in the final extract—which is highly undesirable. The study of the conditions for the proper collection and preservation of the pituitary glands is, therefore, of great significance.

Vitamin C is an important constituent of the pituitary glands (where it is present in greater concentration than in the adrenal glands) and a study of the changes in the vitamin content during collection and storage of the glands should give an insight into the stability of the glands. A detailed study was, therefore, undertaken of the vitamin C content of the glands collected and stored under different conditions: the methods used were firstly the titration method with the oxidation reduction indicator 2:6 dibromophenol-indophenol, and secondly, titration with standard iodine solution. As in the case of a previous study[1] on the preservation of adrenal glands, the iodine titration method was found to give consistently higher values than the indicator method, indicating the presence of extraneous reducing agents.

Tables 1 to 6 represent the figures for vitamin C (expressed as mg. of vitamin per g. of whole gland) obtained for the pituitary glands of cattle and sheep collected (1) in 'dry ice' (— 80°), (2) in freezing mixture (— 18°) and (3) melting ice (0°), soon after the animals were slaughtered and analysed within two to three hours (the time taken for transport of the glands from the abattoir to the laboratory).

Cattle Glands

TABLE 1
Collected in 'dry ice'

Indicator	Iodine
1·43	1·68
1·41	1·67
1·45	1·72
Average 1·43	1·69

TABLE 2
Collected in freezing mixture

Indicator	Iodine
1·38	1·71
1·36	1·78
1·31	1·68
Average 1·35	1·72

Cattle Glands

TABLE 3
Collected in ice

Indicator	Iodine
1·29	1·55
1·30	1·60
1·31	1·59
Average 1·30	1·58

Sheep Glands

TABLE 4
Collected in 'dry ice'

Indicator	Iodine
1·72	2·04
1·70	2·01
1·84	2·18
Average 1·75	2·08

Sheep Glands

TABLE 5
Collected in freezing mixture

Indicator	Iodine
1·72	2·12
1·68	2·05
—	—
Average 1·70	2·09

TABLE 6
Collected in ice

Indicator	Iodine
1·65	1·95
1·66	2·06
1·58	1·85
Average 1·63	1·95

Tables 7 to 10 represent the vitamin C contents of cattle glands which were transported to the laboratory in melting ice and subsequently stored for varying periods at the Frigidaire temperature of 0 to 5°, with the addition of toluene as preservative.

TABLE 7
Glands stored overnight at 0°

Indicator	Iodine
1·16	1·37
1·19	1·43
1·14	1·41
Average 1·16	1·40

TABLE 8
Glands stored for two days at 0°

Indicator	Iodine
0·90	1·08
0·91	1·11
0·91	1·04
Average 0·91	1·08

TABLE 9
Glands stored for three days at 0°

Indicator	Iodine
0·70	0·86
0·71	0·87
0·69	0·86
Average 0·70	0·86

TABLE 10
Glands stored for four days at 0° (putrefaction sets in)

Indicator	Iodine
0·43	0·59
0·39	0·47
0·34	0·50
Average 0·39	0·52

Tables 11 to 16 represent the changes in the ascorbic acid content of cattle glands, which were brought to the laboratory packed in ice and stored frozen for varying periods at — 7° C. (in the freezing chamber of a frigidaire) with the addition of a few drops of toluene as preservative (except Table 11, where the glands were transported to the laboratory in dry ice).

TABLE 11
Glands brought in 'dry ice' and stored overnight in 'dry ice'

Indicator	Iodine
1·33	1·62
1·36	1·63
1·35	1·58
Average 1·35	1·61

TABLE 12
Glands stored overnight at — 7°

Indicator	Iodine
1·30	1·62
1·26	1·62
1·24	1·58
Average 1·27	1·61

TABLE 13
Glands stored for three days at — 7°

Indicator	Iodine
1·27	1·60
1·26	1·58
Average 1·27	1·59

TABLE 14
Glands stored for one week at — 7°

Indicator	Iodine
1·18	1·49
1·15	1·39
1·13	1·48
Average 1·15	1·45

TABLE 15
Glands stored for two weeks at — 7°

Indicator	Iodine
1·12	1·43
1·11	1·41
1·16	1·46
Average 1·13	1·43

TABLE 16
Glands stored for four weeks at — 7°

Indicator	Iodine
1·02	1·23
1·00	1·21
0·99	1·19
Average 1·00	1·21

It will be clear from the above tables that the ideal way of collection of the glands would be to freeze them immediately after removal from the carcass, either with freezing mixture or preferably with solid carbon-dioxide. As regards the storage of glands, rapid decomposition of the vitamin is observed when the glands are stored at 0-5°: at the end of two days over 25 per cent. of the vitamin is lost and on the fourth day the vitamin content is only a third of the original amount. The glands can, however, be kept frozen for several weeks, without any physical deterioration, in which state it can be conveniently transported to distant places. At the end of three days the decomposition of vitamin C in the frozen glands is only 10 per cent. and even after two weeks the loss in the vitamin is only about 20 per cent.

It has often been pointed out that freezing of glands and subsequent thawing is accompanied by rapid destruction of the active principles due to the mechanical rupture of the cell structure (*cf.* Mills).[2] In the course of our analyses of frozen pituitary glands it was repeatedly observed that thawing of frozen glands (which was effected by contact with cooled water) was accompanied with rapid destruction of the vitamin, unless the glands were immediately assayed for the vitamin content. The following tables (17, 18 and 19) represent three typical sets of results obtained on analysis of the vitamin content of frozen glands (the freezing being effected with dry ice, freezing mixture and keeping in freezing chamber at — 7), the entire batch of glands being thawed in one lot and the extraction being spread over 30 to 60 minutes.

TABLE 17

Thawing of glands frozen with dry ice

Indicator	Iodine
1·43	1·68
1·28	1·55
1·23	1·45

TABLE 18

Thawing of glands frozen in freezing mixture

Indicator	Iodine
1·26	1·75
1·08	1·47
1·00	1·27

TABLE 19

Thawing of glands kept in freezing chamber

Indicator	Iodine
1·03	1·35
0·87	1·21
0·72	1·04

It is advisable, therefore, to process the thawed glands without undue delay for the isolation of the active principles.

The following tables (Nos. 20 and 21) represent the distribution of vitamin C in the anterior and the posterior lobes of the pituitary glands of cattle and sheep, the analyses being carried out on fresh glands transported to the laboratory, packed in dry ice.

TABLE 20

The distribution of vitamin C in the cattle pituitary

Anterior lobe		Posterior lobe	
Indicator	Iodine	Indicator	Iodine
1·47	1·90	0·82	1·23
1·49	1·95	0·79	1·30

TABLE 21

The distribution of vitamin C in the sheep pituitary

Anterior lobe		Posterior lobe	
Indicator	Iodine	Indicator	Iodine
1·50	1·82	0·56	1·12
1·56	1·83	0·54	1·05

Vitamin C is thus present in higher concentration in the anterior lobe than in the posterior—an observation in conformity with the findings of Phillips and Stare.[3]

The expenses of this investigation were met entirely by the Board of Scientific and Industrial Research, to whom our grateful thanks are due.

1. Dey, Krishnan and Srinivasan, *Curr. Sci.*, 1943, **12**, 244. 2. Mills, *Biochem. J.*, 1932, **26**, 704. 3. Phillips and Stare, *J. Biol. Chem.*, 1934, **104**, 351.

DR. C. W. B. NORMAND, M.A., D.Sc., C.I.E.

WE learn with great pleasure of the award of the Symons Gold Medal of the Royal Meteorological Society to Dr. C. W. B. Normand, Director-General of Observatories, India.

Awarded for outstanding work in meteorology, the Symons Medal is among the highest honours that a worker in meteorology in Great Britain or abroad can aspire to. The honour is conferred upon distinguished meteorologists of world-wide reputation every two years, alternately for work in Great Britain and abroad. Dr. Normand has received the medal for his work in India; but, nevertheless, his most outstanding work, *viz.*, on the thermodynamics of the wet-bulb thermometer, has universal application to the atmosphere over all regions.

Dr. Normand, a distinguished student of physical chemistry of the Edinburgh University, has been a member of the Indian Meteorological Service since 1913, and for the last sixteen years the Head of the Indian Meteoroloical Department. Ever since he joined the Department his work has been in meteorology, and his deep understanding of thermodynamics has been of particular service to him in tackling some of the complicated problems of stability and instability of the atmosphere. He has devoted considerable thought and hard work for years to his favourite problems. He has not yet made public all the results of his investigations, but the quality of the work he has so far published has already earned international recognition and also the high honour that the Royal Meteoroloical Society has now conferred on him for which we offer him our congratulations.

We may here recall the names of some of the renowned meteorologists of the world who have been the previous recipients of the Symons Medal: Among others they have been Sir Napier Shaw, Hann, Hildebrandsson, Bjerknes, Hergessel, Schmidt, W. H. Dines Sir G. C. Simpson, Sir G. T. Walker and Lt.-Col. Ernest Gold.

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QUASI-LATIN SQUARES IN EXPERIMENTAL ARRANGEMENTS

In the thesis submitted by the author in 1943 to the Calcutta University, it was shown how the Design of Experiments consists of the Fundamental problem together with the problem of Balancing and the Construction of designs. Every experimental design is a mathematical solution to a combinatorial problem directly deducible from the mathematical model set up by the necessary balance and other requirements such as the block size, number of replications, cost of experimentation, etc., required by the experimenter. Two types of designs called as 'The partially balanced design' and 'The Intra- and Inter-group balanced design', gave a variety of designs in the case of incomplete block designs. These two systems, also, gave balanced or partially balanced confounded designs in the case of general factorial experiments, asymmetrical or symmetrical. It is proposed to extend these ideas to Quasi-Latin squares which are suggested by Fisher's requirement of the 'local control' by which the efficiency of an experimental design may be enhanced by minimising the error without increasing the number of replications. These were first introduced by Yates[1] in the case of incomplete block designs.

The Fundamental Problem.—The most general set up consists of v treatments denoted by $T_1, T_2, T_3 \ldots T_v$ tested in n lattice square arrangements of s^2 cells each, such that the i-th treatment is replicated r_i times and the treatments T_i and T_j appear together in columns and rows combined λ_{ij} times and in squares, on the total μ_{ij} times. The parameters are connected by the following relationships:—

$$\lambda_{ii}=0$$
$$\lambda_{ij}=\lambda_{ji},\ \mu_{ij}=\mu_{ji}$$
$$\Sigma r_i=n s^2$$
$$2(s-1) r_i=\sum_j \lambda_{ij}$$
$$r_i(s^2-1)=\sum_j \mu_{ij}$$

Analysis of the General Design.—Using the methods of analysis developed in the above thesis we get the estimating equation as,

$$Q_i=r_i(s-1)^2 t_i - s\sum_j \lambda_{ij} t_j + \sum \mu_{ij} t_j$$

where t_i estimates the effect of the treatment T_i, and

$Q_i = s^2$ (sum of observations of the i-th treatment)
$- s$ (sum of row and column totals in which the i-th treatment occurs)
$+$ the weighted sum of square totals the weights being number of times the i-th treatment occurs in a square.

From these set of equations, we can test the significance of any estimable linear expression of the treatment effects by comparing it against its estimated standard error. The estimates of linear expressions being linear functions of Q_i, their standard errors, ultimately, depend on the following results. Let Q_i be gathered from m_i lattice squares the contribution from the j-th square being q_{ij}.

$$Q_i=\Sigma q_{ij}$$
$$V(Q_i)=\sum_j V(q_{ij})$$
$$V(q_{ij})=r(s-2s+r)^2+(s-r)^2 2r+(s-r)^2 + r(r-1)(r-2s),^2$$

when the i-th treatment occurs r times in j-th lattice square.

$$\text{Cov}\,(Q_iQ_m) = \Sigma\,\text{Cov}\,(q_{ij}q_{mj}).$$

The most general expression for the covariance has been found out but is not given here due to lack of space. There are two types of designs which appear to be fruitful.

Type 1.—Let $s\lambda_{ij} - \mu_{ij} = v_{ij}$. We impose restrictions on v_{ij} similar to that of the partially balanced design (it may be noted that the second system of parameters introduced by Bose and Nair[2] are restrictions on the parameters v_{ij}) or the Intra- and Inter-group balanced design of the incomplete blocks. Thus we get two subtypes in type 1.

Type 2.—$\mu_{ij} = \mu$ $i \neq j$, independently of i and j. In this case we impose restrictions on the parameters λ_{ij}. We get two subtypes by allowing the parameters to satisfy the conditions of the partially balanced or the Intra- and Inter-group balanced design of the incomplete block designs.

Various methods of construction of the designs such as the geometrical and the method of differences developed by Bose[3] and used by the author have been found out and a full list of practically useful designs will be given in an elaborate paper to be published shortly. Also the Quasi-Latin squares used for double confounding in factorial experiments, the necessary and the sufficient condition for which has been given by the author in the work referred to, come out as special cases.

Statistical Laboratory,
Calcutta, C. RADHAKRISHNA RAO.
October 4, 1943.

1. Yates, *Technical Communication* 35, *Imp. Bureau Soil Science*. 2. Bose and Nair, *Sankhya*, **4**, 337–72. 3. —, *Ann. of Eugen*, **9**, 358–99.

CATALYSIS OF THE INTERACTION BETWEEN HYDROGEN SULPHIDE AND SULPHUR DIOXIDE BY SILVER SULPHIDE

IN the course of an investigation on the influence of moisture on the interaction between hydrogen sulphide and sulphur dioxide ($2\ H_2S + SO_2 \rightarrow 2\ H_2O + 3\ S$), it was noticed that the reaction between the two gases occurred only to a small extent at the surface of pure silver powder but that the reaction was highly autocatalytic, owing to the production of silver sulphide, which vigorously catalysed the union. For instance, in a representative experiment where the volume of the gases was kept constant (the reaction vessel being in an air thermostat at 32°·5 C.) the fall in pressure due to interaction at the surface of silver was only 13 mm. during the first 70 minutes and the silver gradually acquired a dark colour, owing to the formation of silver sulphide. During the next 20 minutes, however, owing to the catalytic effect of silver sulphide, the fall in pressure was 103 mm.

The progressive formation of water during the above reaction greatly enhanced the autocatalytic nature of the reaction, the activity of silver sulphide being proportional to the vapour pressure of water in the system. Using a hygrostat (mixture of suitable hydrate and its anhydrous form, *e.g.*, oxalic acid, barium bromide) the vapour pressure of water in the reaction vessel could be controlled and the effect of moisture on the catalytic activity of silver sulphide studied. When phosphorus pentoxide was used as the desiccant, the silver sulphide was inactive.

To catalyse the union of the two gases at the surface of glass, a very much higher vapour pressure of water was found to be necessary, than in the case of silver sulphide. The kinetics of the reaction between sulphur dioxide and hydrogen sulphide, as catalysed by silver sulphide could, therefore, be conveniently investigated in a glass apparatus, wherein the vapour pressure was kept sufficiently low with the aid of an appropriate hygrostat, so that while no detectable reaction took place at the surface of glass, the catalytic activity of silver sulphide was adequate.

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October 6, 1943.

CATALYTIC ACTIVITY OF SILVER SULPHIDE

SILVER SULPHIDE, which had been found by one of us to catalyse the union between hydrogen sulphide and sulphur dioxide, was noticed to have an equally remarkable catalytic effect on the decomposition of sulphur monoxide (and its polymer S_2O_2). The monoxide, prepared by the combustion of sulphur in carefully dried oxygen under a pressure of 5 mm. of mercury, was passed over silver sulphide and found to undergo rapid decomposition as indicated by the increase in weight of the sulphide, due to sulphur deposition. In one series of experiments, wherein the same sample of silver sulphide was used as catalyst, the sulphur produced by decomposition of the monoxide was 30·5, 22·4 and 20·0 mg., the corresponding volumes of oxygen employed in the combustion of sulphur being 195, 210 and 250 c.c. A noticeable fall in efficiency of the sulphide occurred as the catalyst got covered by sulphur. In another experiment, when a fresh sample of catalyst was used, the weight of sulphur deposited was 265 mg. when 4 litres of oxygen were employed for combustion.

Silver sulphide was also found to rapidly catalyse the reaction between hydrogen sulphide and sulphur monoxide, even when both the gases had been carefully dried over phosphorus pentoxide. As in the previous experiments, the sulphur liberated during the reaction, was determined by measuring the increase in weight of the silver sulphide. Water formed, was absorbed in a phosphorus pentoxide tube and weighed. As was to be expected, two reactions took place simultaneously at the surface of the catalyst—the decomposition of sulphur monoxide and the reaction between hydrogen sulphide and sulphur

monoxide in terms of the equation $SO+H_2S = 2S + H_2O$. It was not practicable to suppress completely the decomposition of sulphur monoxide at the surface of silver sulphide, but by increasing the proportion of hydrogen sulphide to that of oxygen* used in the combustion of sulphur, the extent of the interaction between hydrogen sulphide and sulphur monoxide could be increased, as could be gathered from results obtained in a set of experiments:—

Ratio H_2S/O_2	Wt. S in mg.	Wt. H_2O in mg.	Ratio S/H_2O
1·0	32·0	5·0	6·4
1·6	19·0	4·2	4·5
4·0	11·5	3·0	3·8

If the interaction between hydrogen sulphide and sulphur monoxide was the only reaction taking place at the catalyst surface, the ratio of sulphur to water would be 3·6. It has to be noted that the sulphur dioxide produced along with the monoxide during the combustion of sulphur, does not react with hydrogen sulphide at the surface of silver sulphide when phosphorus pentoxide is used as the desiccant for the two gases. Further work is in progress.

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October 6, 1943.

*No accurate method that can conveniently be employed, is at present available for the determination of sulphur monoxide in the products of combustion. Conditions under which the sulphur was burnt were kept as constant as possible, and it was assumed that the sulphur monoxide produced was directly proportional to oxygen used in combustion. A method for the accurate determination of sulphur monoxide, based on its catalytic decomposition by silver sulphide, is now being developed in this laboratory.

A SENSITIVE METHOD FOR THE ESTIMATION OF COMMON VOLATILE TRIHALOGEN ANÆSTHETICS IN THE BLOOD AND TISSUES OF ANIMALS

Fujiwara[1] in 1914 found that chloroform in the presence of alkali gives a pink colour with pyridine and that the method can detect chloroform in dilutions upto 1 in a million. Cole,[2] in 1926, utilised this method for determining the concentration of chloroform in the body tissues. Recently Daroga[3] *et al.* have stabilised the colour produced by adding a little acetone. All these applications of Fujiwara reaction suffer from a drawback that the colour obtained is not quite clear due to the presence of protein in tissues and blood and that the colour of the blood interferes with the estimations. The present work is concerned with a new method where the Fujiwara reaction has been employed to detect and estimate the common trihalogen volatile anæsthetics in the blood and other body tissues.

Method

5 c.c. of blood from an animal anæsthetised with chloroform or trichlorethylene are put in a 1½" diameter test tube containing 40 c.c. of distilled water and 5 c.c. of 0·05 per cent. saponin solution. The test-tube is fitted with a rubber cork through which pass two tubes, one as an entry for air and the other as an exit for it. The exit is bent twice at right angles and passed into another rubber cork with a condenser arrangement fitting to a similar test tube and containing 20 c.c. of pyridine. The exit tube dips into pyridine. The pyridine test tube is immersed in ice and ice water is circulated in the condenser which is fitted to it. The condenser exit is passed through rectified spirit which acts as a trap. Care is taken to see that all the connections are air-tight except the last exit. The blood is now air-distilled and the quantity of chloroform or trichlorethylene present in the blood is absorbed in pyridine. The current of air is passed for one and half hours and after this period the test tube containing the hæmolysed blood is heated to about 80° C. by gentle heat, while the current of air is continued. After 2½ hours the apparatus is disconnected. The trap of rectified spirit is always tested for the presence of the anæsthetic. It is found that as long as the pyridine test tube and the condenser are properly cooled no anæsthetic could be detected in the trap. The pyridine in the test tube which now contains chloroform or trichlorethylene is taken for qualitative and quantitative estimations.

The pyridine containing the anæsthetic is diluted 1 in 4 with fresh pyridine. 5 c.c. of this solution are transferred to a long test tube containing 10 c.c. of 20 per cent. alkali [NaOH] and then lightly plugged with cotton wool. The test tube is now dipped into a boiling water bath for 1½ minutes and then cooled in ice. The coloured pyridine layer is transferred to another test tube and compared in a Leitz colorimeter with the colour produced by a standard solution of the anæsthetic prepared in pyridine. The concentration of the standard is usually 1·2 mg./100 c.c. The colour is stable for half an hour after removal if it is kept cold and no acid vapours are allowed to come in contact with it.

For estimating the anæsthetic in tissues, the tissue is finely minced and ground in a mortar and pestle, the whole operation being performed under acidified ice-cold water. The acid-water along with the suspended tissue is then transferred to a wide test tube and the procedure described above followed.

The method was standardised by estimating a known quantity of chloroform or trichlorethylene added to the blood. The following table shows some of the results obtained and the percentage variation between the actual quantities added and those that are estimated.

With this method the concentrations of chloroform in the blood of various animals

No.	Name of Anæsthetic	Quantity added	Quantity estimated	Variation per cent.
1	Trichlorethylene	1·4 mg./200 c.c.	1·25 mg./200 c.c.	−0·075 mg./100 c.c.
2	Chloroform	1·125 mg./100 c.c.	1·325 mg./100 c.c.	+0·20 mg./100 c.c.

were determined and it was found that in all these cases the results obtained which will be published later are in close agreement with the recent findings of other workers.

My thanks are due to Dr. B. B. Dikshit for his keen interest in the work. My thanks are also due to Lt.-Col. Sokhey, I.M.S., Director, Haffkine Institute, for the facilities given for carrying out the work.

Pharmacological Dept.,
Haffkine Institute,
Bombay, R. N. KULKARNI.
October 14, 1943.

1. Fujiwara, *Sitzmgsb u. Abhandl., Naturfors*, 1914, **6**, *l. Ges. Rostock. Chem. Abs.*, 1917, **11**, 3201. 2. Cole, *J. Bio. Chem.*, 1926, **71**, 173. 3. Daroga & Pollard, *J. Soc. Chem. Ind.*, 1941, **60**, 218.

PANICUM MILIACEUM (GUJARATI-CHENA), A NEW RAW MATERIAL FOR STARCH INDUSTRY

THE fall in the imports of starch into India, and the increased demand for sizing agents for the textile industry, have rendered the search for a suitable indigenous source of starch both urgent and necessary. In view of the prevailing food scarcity, cereals like wheat, maize and jawar are no longer available for industrial purposes. Attempts to utilise, for the first time, the corn *Panicum miliaceum*, which is grown in Gujarat as a side crop during both the rainy and hot seasons, have proved eminently successful. The normal yield of this crop is 20 maunds per acre. The stems and roots of this corn are used as manure. The straw provides excellent fodder in considerable quantity when there is scarcity of fodder. The following is the chemical composition of the grain:—

Moisture 7·8 per cent., Ash 4·95 per cent., Fibre 9·75 per cent., Fat 4·0 per cent., Protein 9·06 per cent., Carbohydrates 64·44 per cent.

The usual treatment of corn, i.e., steeping, milling, caustic treatment and tabling, yields 52 per cent. of pure starch. The starch in microscopic appearance resembles maize starch and possesses the following properties, to recommend its use as a sizing agent in the textile industry:—

The gelatinisation temperature is 76° C.

The following table gives a comparative idea of the viscosity in relation to maize and wheat,

Effect of continued heating at 90° C. on change in viscosity.

(In $^1/_5$ seconds) (By Stormer Viscometer)

3% Starch paste	10 Mts.	15 Mts.	20 Mts.	25 Mts.	30 Mts.	60 Mts.	120 Mts.	180 Mts.	240 Mts.	360 Mts.
Maize ..	57	52	51	51	51	49	45	41	39	37
Wheat .	45	46	46	43	43	39	37	36	35	34
Panicum miliaceum (Chena) ..	37	40	—	41	44	49	54	50	48	40

On large-scale sizing test carried out in textile mill, the results of this starch have been found to be identical to that of the maize starch.

Further, the waste bran obtained after separation of starch from the corn contains 11·4 per cent. protein matter which compares favourably good with other cattle-feeds.

Industrial Chemist's Laboratory,
Sayaji Technological Institute,
Baroda, C. B. PATEL.
October 15, 1943.

N¹-SULPHANILYL-ISOTHIOUREAS

ALTHOUGH the preparation of many N¹-sulphanilyl-derivatives of urea, thiourea, guanidine, etc., has been described, there appears to be no systematic study of N¹-sulphanilyl-isothiourea derivatives reported in literature. As these bear structural resemblance to sulphathiazole the following derivatives

(I) acetylaminobenzenesulphonyl-ethylisothiourea, m.p. 180-1°;
(II) acetylaminobenzenesulphonyl-propylisothiourea, m.p. 174°;
(III) acetylaminobenzenesulphonyl-butylisothiourea, m.p. 157°;
(IV) acetylaminobenzenesulphonyl-allylisothiourea, m.p. 173-74°; and
(V) acetylaminobenzenesulphonyl-benzylisothiourea, m.p. 171-73°;

have now been prepared from the corresponding alkyl isothiourea hydrochlorides and hydrobromides using standard methods.

The free bases corresponding to compounds (I) to (IV) are obtained by digestion with 8-10 per cent. aqueous hydrochloric acid for 15-20 minutes, and they melt respectively at 155-56°, 133-34°, 116° and 170°. Roblin *et al.*[1] prepared the free base of the compound (I) by hydrolysing it with alcoholic hydrochloric acid for two minutes. It has now been found that the hydrolysis of the compounds (I) to (IV) is not carried to completion by this method. Hydrolysis of the compound (V) by the above methods is attended with disruption of the molecule, yielding only sulphanilic acid and benzylmercaptan. Further work on the condensation of other isothiourea hydrobromides

with p-acetylaminobenzenesulphochloride is in progress.

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V. MAHADEVAN.

Organic Chemistry Laboratory,
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Bangalore,
November 6, 1943.

1. Roblin, *et al.*, *J. Amer. Chem. Soc.*, 1942, **64**, 1682.

THE ROLE OF TRYPTOPHANE IN BLOOD FORMATION

ON purely chemical grounds the essential function of tryptophane in the animal organism has been considered to be that of providing the pyrrole ring for the synthesis of hematin. But the experiments designed to throw light on the relation of this amino-acid to blood formation have yielded contradictory results. The beneficial effect of tryptophane injections in experimental anæmia in animals has been reported by Hirasawa (1921),[1] Okagawa and Tatsui (1931)[2] and by Iwakura, Otani and Taniguchi (1933).[3] Fontés and Thivolle (1930)[4] claim to have produced anæmia in rats by feeding them on tryptophane-deficient diets and to have rendered normal animals hyperemic by injection of tryptophane or a tryptophane histidine mixture. Alcock (1933)[5] was, however, unable to confirm either of these observations of the French authors. Hæmoglobin regeneration in animals suffering from milk anæmia was found by Alcock to be unaffected by administration of tryptophane, nor could he render animals anæmic by depriving them of the amino-acid. From determinations of the tryptophane and histidine content of the blood of patients suffering from pernicious and hæmorrhagic anæmia Tochowicz (1936)[6] similarly concluded that these amino-acids play no important part in blood formation.

In the experiments now reported the effect of tryptophane deficiency in the diet was studied in the first place on normal rats and secondly on rats made anæmic by means of phenylhydrazine injections.

The experimental diet consisted of the following:—Casein (whole or hydrolysed), starch, sugar, butter fat and Steenbock's salt mixture. The vitamins were supplied in the form of yeast and cod-liver oil. Hydrolysed casein provided the tryptophane-deficient diet.

In experiments on normal rats three groups were used, group I receiving whole casein, group II hydrolysed casein plus 20 mg. of tryptophane per rat per day, and group III hydrolysed casein.

R.B.C. determinations were made at the beginning and at the end of the experiment which lasted one month. The average values for R.B.C. in each group are given in Table I, from which it will be seen that the values are slightly lower for animals receiving no tryptophane in the diet than those on the whole casein or hydrolysed casein plus tryptophane. This slight difference was repeatedly found in different series of experiments, but the results are not statistically significant.

However, striking differences due to the absence of tryptophane in the diet were found when animals were first made anæmic by phenylhydrazine as described previously (Yeshoda, 1942).[7]

The results of one experiment on two groups of eight such animals, one receiving hydrolysed casein, the other hydrolysed casein plus tryptophane are summarized in Table II which gives the average increases for R.B.C. and hæmoglobin in each group in twelve days after the stage of acute anæmia. Statistical examination of the values for individual animals in the two groups show the results to be highly significant. Curve I shows clearly the differences in the rates of recovery of the animals in the two groups. While the animals receiving tryptophane had regained their normal R.B.C. values in twelve days and their normal hæmoglobin values in fifteen days, the corresponding periods for the rats in the tryptophane deficient group were about thirty days, and even then the values for both R.B.C. and hæmoglobin were slightly below normal.

There can be no doubt from these experiments that tryptophane plays an important

TABLE I

	Casein			Hydrolysed casein + tryptophane			Hydrolysed casein		
	Days		Increase	Days		Increase	Days		Increase
	0	30		0	30		0	30	
R.B.C. in millions per c.mm.	7·06	8·03	·97	7·12	8·03	·91	6·97	7·49	·52

role in blood regeneration. It is true that, as in Alcock's experiments, in normal animals tryptophane deficiency produces no marked anæmia, but this must be explained on the assumption that blood composition is maintained constant by utilization of tryptophane derived from tissue wastage as is proved by the fact that although animals on a tryptophane-deficient diet present a nearly normal blood picture, they loose weight continuously during the experimental period.

TABLE II

	Hydrolysed casein + tryptophane			Hydrolysed casein		
	Days		% Increase	Days		% Increase
	0	12		0	12	
R.B.C. in millions per c.mm.	3·04	6·45	112·1	3·06	4·75	55·24
Hæmoglobin in gm. per 100 mm.	8·34	13·7	63·52	8·39	11·77	40·28

	R.B.C.	Hæmoglobin
Standard error of difference	17·9	6·77
Value of t	4·66	11·95

The author's thanks are due to Prof. M. Damodaran for his valuable help and interest in the work, and to Dr. N. Sundararama Sastri for the statistical analysis of the results.

University Biochemical Laboratory, Madras, *November* 8, 1943. K. M. YESHODA.

1. Hirasawa, *J. Osaka Med. Soc.*, 1922, **21**, 9. 2. Okagawa and Tatsui, *Z. Physiol. Chem.*, 1931, **195**, 192. 3. Iwakura, Otani and Taniguchi, *Ibid.*, 1933, **214**, 22. 4. Fontes and Thivolle, *Le Sang*, **6**, 658. 5. Alcock, *Biochem. J.*, 1933, **27**, 754. 6. Tochowicz, *Folia Hæmatol*, 1936, **56**, 240. 7. Yeshoda, *Curr. Sci.*, 1942, **11**, 360.

THE INDUCED OXIDATION OF OXALIC ACID BY DICHROMATE WITH FERROUS SULPHATE AS INDUCTOR

DURING the course of some other work we discovered that the presence of oxalate interferes with the titration of ferrous sulphate with dichromate by giving rise to a consumption of dichromate far in excess of the amount required for the oxidation of the ferrous iron present. This excess consumption of dichromate cannot be explained as due to any primary reaction between oxalate and dichromate, for it is known from the work of Dhar[1] that oxalic acid is only slowly oxidised by dichromate at ordinary temperatures.

Further, we have observed that, in the absence of ferrous sulphate, oxalate at the concentrations employed in our experiments does not consume any dichromate, the deep blue colour indicative of the end point with the diphenyl amine reagent being produced by the addition of a single drop of dichromate. Detailed experiments carried out by us have led to the conclusion that the observed interference of oxalate is due to the fact that the rapid reaction between ferrous sulphate and dichromate induces the reaction between oxalate and dichromate.

The following table incorporates some of the typical results:—

10 c.c. N/20 $FeSO_4$ + 5 c.c. 4N H_2SO_4 + 2·5 c.c. H_3PO_4 (1·75 Spgr) + 0·5 c.c. 0·1% diphenylamine + X c.c. oxalate + water to make up the volume to 50 c.c.

Concentration of oxalate	Amount of dichromate 0·0529 N (in c.c.)	Induction factor (F) $F=\frac{\text{No. of moles of oxalate oxidised}}{\text{No. of moles of } FeSO_4 \text{ oxidised}}$
Nil	9·45	
0·01N	12·05	0·14
0·03N	14·15	0·25
0·05N	14·80	0·28

From the results given in the above table, it will be seen that the induction factor increases with increasing concentration of oxalate the concentration of ferrous sulphate and hydrogen ion being kept constant.

We have also found that ferrous sulphate induces the reaction between dichromate and tartaric, citric, and malic acids but not succinic acid.

Andhra University, *November* 17, 1943. C. R. VISWANADHAM. G. GOPALA RAO.

1. Dhar, N. R., *Trans. Chem. Soc.*, 1917, **111**, 707.

AN IMPROVED METHOD OF LOCATING TANNINS IN PLANT SECTIONS

COMMON TESTS FOR TANNINS

VARIOUS methods[1] have been described for locating tannins in plant tissues, but they all suffer from one disadvantage or the other. Vinson[2] fixes and stains tannins *in situ* by exposing whole organs to vapour of amyl or ethyl nitrite. He recommends a 20 per cent. alcoholic solution of ethyl nitrite, but, owing to its low boiling point (16° C.) it volatilizes so rapidly at the temperatures prevailing in this country, that in practice it becomes difficult to get satisfactory results. Amyl nitrite on the other hand though less volatile, is disagreeable to use.

Methylene blue (1 : 500,000) followed by saturated aqueous picric acid, has also been

recommended for staining tannins in the living state[3] but the test is not very specific as other tissues besides tannins are also stained.

One of the most commonly used methods for detecting tannins in plant sections is to draw a drop of 10 per cent. ferric chloride under the cover glass by means of filter paper.[4] The tannins are stained dark green, blue or black. The method is very useful especially when there is a high accumulation of tannins as in galls or near wounds or infected tissue. But as the test is not very sensitive it cannot be successfully used when the concentration of tannin in the tissues is very low (1-10 p.p.m.).

Recently Dastur[5] has prepared standard slides of sections of cotton leaves, showing different degrees and extent of tannin accumulation, but unfortunately he has not described the technique employed.

Advantages of Folin Denis Reagent (F.D.R.)

The author while working on the causes of discolouration of jute during retting tried the above methods for locating the tannins in the stem sections but without any success. It was then, that the idea of using Folin Denis Reagent suggested itself. F.D.R. has previously been used with a great amount of success as delicate test for microquantities of tannins as 1 p.p.m.$^{-6}$; but the possibility of its being used as a new stain in histological work has never been explored. The author after repeated trials has been able to develop a standard technique by which F.D.R. can successfully be used as a delicate and reproducible test for locating the tannins in plant sections.

The method is simple and presents great advantages over those described before. In the first place it is very specific, no other tissues besides those containing tannins being stained. In order to verify its specific nature, sections of different plant materials were separately stained with standard lignin and cellulose stains, *viz.*, phloroglucin, Maule, anilin sulphate, Schultze's solutions, iodine followed by sulphuric acid and also F.D.R., and examined under the microscope. It was found that tissues which gave a positive reaction either for lignin or for cellulose were in many cases not stained by F.D.R. For instance the xylem or wood though mostly lignified was not stained blue with F.D.R.; so also the pith and rays which are predominantly cellulosic in character, showing thereby that F.D.R. is neither a lignin nor a cellulose stain. Cellulose and lignified tissues are stained by F.D.R. only in the presence of tannin. Thus cotton fibres and filter-paper pulp do not show any colour when stained with F.D.R. but the same materials when treated with F.D.R. after a preliminary steeping in tannin (10 p.p.m.) give a distinct blue colouration.

The method is also more sensitive than any of those described earlier and can be used with very good results even when the concentration of tannins in the tissues is as low as 1 p.p.m. Staining is also permanent. It has been successfully tried for number of plants like flax, tea, jute, etc., and is described below.

The F.D.R. Method for Detecting Tannins in Plant Section

Preparation of reagents.—Only two solutions are required and they are prepared as follows:—

A. 2·25 gms. of phosphotungstic acid, 0·5 gm. of phosphomolybdic acid and 1·5 c.c. of syrupy phosphoric acid are taken in a small conical flask to which are then added 17·5 c.c. of distilled water. The mixture is boiled over a water-bath under reflux for two hours, allowed to cool and then made up to 25 c.c. by adding the required quanitity of distilled water. The solution deteriorates on exposure to strong light, and it is advisable to keep it in an amber coloured bottle preferably wrapped in black paper.

B. A saturated aqueous solution of sodium carbonate is prepared by boiling 70-75 gms. of anhydrous sodium carbonate with 100 c.c. of distilled water till dissolved. The solution is allowed to cool and settle down and the clear liquid from the top is then decanted and if necessary filtered before use.

Procedure.—As the stain is aqueous the sections have to be brought down to distilled water before applying the stain. The sections are covered with just sufficient quantity of solution A for about 15-30 minutes though with fresh green sections even 5 minutes were found to be quite sufficient. The solution is then drained off and the sections neutralized with a few drops of solution B. The staining is complete when the effervescence due to escape of carbon dioxide ceases. A blue colour is obtained with the formation of a cloudy white precipitate. No attempt should be made to remove the white precipitate by washing the sections in water as the blue stain is readily soluble in water. As soon as neutralization is effected the sections are quickly passed through 30, 50, 70, 85, 95 per cent. and absolute alcohol, cleared in xylol and mounted in balsam. Tissues containing tannins are stained a deep, steel-blue. The staining is permanent and the preparations keep well.

Material Studied

The author has tried the method with uniformly good results for a number of plants. In jute, only the fibre bundles of the phloem are stained the tannins being located in the cell walls, contrary to the findings of Nodder.[7] According to Kundu,[8] in jute, the dark deposits which occur abundantly in the cortex and rays are tannins, but they do not take any stain with F.D.R. which clearly shows that they are not tannins. Their chemical nature, however, appears to be in doubt.

A list of plant materials where the presence of tannins has been demonstrated by the above method is given below.

Stem.—*Corchorus capsularis, C. olitorius, Hibiscus sabdariffa, H. rosasinensis, H. esculentus, Crotalaria juncea, Linum usitatissimum, Cajanus indicus, Mangifera indica, Ricinus communis* Rosa sp.

Twigs.—*Camellia Thea, Gossypium* sp., *Sesbania grandiflora.*

LEAVES.—*Agave sisalana Bromelia* sp.
FRUIT.—*Musa* sp., *Gossypium* sp.

Jute Agricultural Research
Laboratories, Dacca,
Indian Central Jute Committee,
October 4, 1943. A. C. BOSE.

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A NEW ASCOMYCETOUS FUNGUS ON *SELAGINELLA*

THE fungi, so far recorded on *Selaginella*, are *Pythium Debaryanum* and *Synchytrium Selaginellæ* among the Phycomycetes; *Taphrina Selaginellæ*, *Acrospermum urceolatum* and *Leptosphæria helvetica* among the Ascomycetes; the Deuteromycete *Phyllosticta Selaginellæ*; and two smuts *Melanotœnium Selaginellæ* and the Indian specimen *Entyloma polysporium*.[1] According to some[2] the smut recorded from India[3] as *Entyloma* bears greater resemblance to the genus *Melanotœnium*. Recently Sydow[4] has described *Melanotœnium oreophilum* as a new species on two Indian Selaginellæ.

The present specimen is an Ascomycete belonging to the order Sphæriales and the family Sphæriaceæ. The minute perithecia are globose and black and are found superficially in groups at the tips of vegetative shoots or sporangiferous spikes. They are black, smooth, hard, devoid of hairs and lack long beaks. However, an ostiole, situated on a minute papilla, is clearly visible under a lens. The ascospores, which are eight in number in each ascus, are oblong to spindle-shaped, hyaline and bi-celled. Paraphyses are present.

The fungus thus agrees with the description given[5,6] for the genus *Melanopsamma* to which it belongs. Studies based on microtome sections as well as measurements of spores, asci, etc., show that it is a new species. An interesting feature of this fungus is that its hyphæ grow down to a considerable extent, along the vascular bundle, from the tip, but do not affect other parts of the stem such as endodermis, cortex, etc., or the leaves. A full description of the fungus together with the naming of the species will be given elsewhere. It may be noted here that this is also the first record of *Melanopsamma* on any host in India. Butler and Bisby[7] and Mundkur[8] do not mention anything about this genus.

The present fungus was found growing on living *Selaginella chrysocaulos* in the Lloyd Botanical Gardens, Darjeeling, in the month of September.

Department of Botany,
University of Allahabad, A. K. MITRA.
October 5, 1943.

1. Verdoorn, Fr., *Manual of Pteridology*, 1938, p. 156. 2. Maheswari, P., and Puri, V., *Curr. Sci.*, 1935, **3**, 301. 3. Singh, T. C. N., *New Phytologist*, 1930, **29**, 294–96. 4. Sydow, H., *Annales Mycologici*, 1935, **33**, 367 5. Winter, G., *Rabenhorst's Kryptogamenflora*, 1887, p. 238. 6. Saccardo, *Sylloge fungorum*, Vols. 1–24. 7. Butler and Bisby, *Fungi of India*, 1932. 8. Mundkur, B. B., *Fungi of India*, Supplement 1, 1938.

CASES OF ANTIPODAL POLYEMBRYONY IN *ALANGIUM LAMARCKII* Thw.

A DETAILED review on polyembryony has already been published by Webber.[2] In most of the cases multiple embryos are formed by nucellar budding and these are sporophytic in nature. Development of additional embryos from the antipodals are comparatively of rare occurrence. Cases of antipodals developing further into adventitious embryos are reported by Ernst[1] in *Allium* and Woodsworth[3] doubtfully refers to such cases in *Alnus rugosa*.

In the course of the studies on the Gametogenesis and Embryogeny in *Alangium Lamarckii* Thw., the writer noticed in many cases, the antipodals developing into immature embryos. In normal cases the antipodal nuclei degenerate just prior to fertilization. But in some cases they become cellular. Such a cell

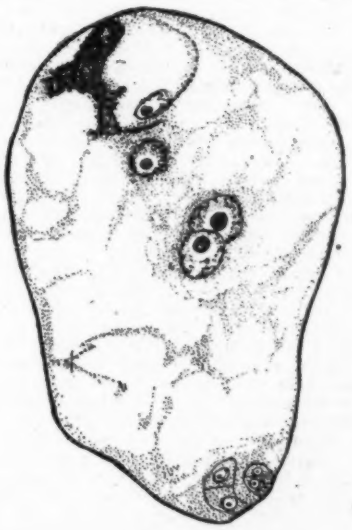


FIG. 1
Embryo-sac of *Alangium Lamarckii* showing antipodal polyembryony. × 700.

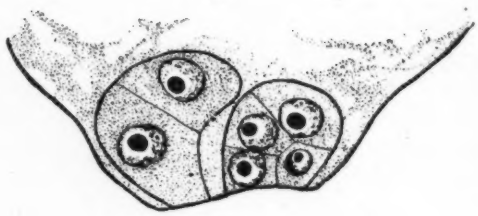


FIG. 2

Antipodal region of the same enlarged ×1900.

divides by mitotic divisions to form a mass of 4 to 6 cells. Usually one to two antipodals of the embryo-sac develop in this manner individually. Further development of these antipodal embryos is arrested probably due to want of nutrition. Only the embryo developed from the fertilised egg matured and this fact has also been confirmed by seed germination tests.

The author is thankful to Dr. L. S. Dorasami, for facilities and guidance and to Mr. M. J. Thirumalachar for helpful suggestions.

Bangalore, D. M. GOPINATH.
October 19, 1943.

1. Ernst, A., "Bastarddierengals Ursache der Apogamie," in *Pflanzenreich*, 1918. 2. Webber, J. M., *Bot. Rev.*, 1940, **6**, 575–98. 3. Woodsworth, R. H., *Bot. Gaz.*, 1930, **89**, 402–09.

ON A VINE CHILLY IN MYSORE

IN Rayarakalhalli, a village six miles from Goribidnur, Mysore State, an unusual type of chilly plant is present. The plants are nearly six years old with apparent scandent habit. Consequently the plants have been supported on other trees. Material for the present study was made available by the kindness of Mr. N. R. Chikkannia, owner of the estate. A previous description of the plant that had appeared in the newspaper "*Hindu*" was based on the plants from the same garden.

The plants favour sciophytic (shade-loving) habitats. They are at present six years old, with branches supported to a height of 17 to 20 feet. An examination of the floral parts indicated that it is beyond doubt *Capsicum frutescens* L., but with minor variations. Comparative studies between the vine chilly plants and the local varieties of *Capsicum frutescens* with respect to floral parts, size, sculpturing and number of germ pores in the pollen grains, anatomy of the leaf-stem and root, and the size and distribution of the stomata, pointed out that the two plants are identical. Further, the similarity of the sizes of the stomata and the pollen indicate the improbability of the vine chilly plant having arisen as a result of polyploidy. In both the vine chilly plants and the local ones the leaves are ovate-lanceolate, with solitary peduncles, white flowers, drooping fruits which are tapering, curved or slightly reflex. The ovary is two-celled and rarely three-celled. A higher percentage of three-celled ovaries, however, occur in the vine chilly plants.

The scandent habit of the plants with branches growing to a length of nearly 20 feet is a feature so far unrecorded in any of the species or varieties of the genus *Capsicum*. A close study of nearly two hundred large plants and seedlings of the vine chilly plants were made with a view to observe if any splitting of characters occurred, thus indicating the heterozygous nature of the plants. In all the cases the plants were true breeding and uniformly similar.

It is manifest that the vine chilly plants are true breeding, closely resembling structurally *Capsicum frutescens* L. It is also apparent that their scandent habit is not due to etiolated conditions but a natural phenomenon. A new variety *Capsicum frutescens* L. var. *scandens* Narasimhan is designated for its accommodation.

A brief history of the plants as obtained from Mr. Chikkannia indicated that a few plants with vine habit were first observed in a plot with seedlings of *Capsicum frutescens* near Koratigere, Mysore State. Since the plants are all true breeding, their origin by way of mutation is not improbable. A detailed cytological study is bound to throw more light on this point. Another feature worth mentioning is that the vine chilly plants are extremely floriferous and the branches do not become scraggy at the end of the year as in the local varieties. Their perennial habit and sciophytic nature can be used with advantage in growing them in cocoanut and areca gardens. An attempt in this direction has already been made.

Dept. of Agriculture,
Bangalore, M. J. NARASIMHAN.
November 24, 1943.

ERGOT ON SUGARCANE IN MYSORE

IN the course of the collections of smuts on sugarcane in Mysore, elongated, yellowish-black sclerotia of ergot were noticed on sugarcane arrows; when they occur in abundance, the unaffected flowers cease to develop but remain sterile. The persistent tuft of bristles at the base of the glumes helps the dispersal of the sclerotia just in the same manner as the normal seeds. Such a mechanism of dispersal has been reported by Stager[1] in the ergot on *Calamogrostis epigeios*.

Ergot on sugarcane has been recorded as stray occurrence from the Philippines by Ocfemia[2] on the basis of the material collected by Messrs. Simon Perez and Pedro Juachon, and has so far not been recorded from any other place. The abundance of sclerotia observed in the present study is encouraging. The mass of flowers in the arrowing varieties of sugarcanes is enormous, and by proper inoculation and dissemination of infection it

should be possible to secure a large-scale production of ergot.

Department of Botany,
Central College,
Bangalore, M. J. THIRUMALACHAR.
November 25, 1943.

1. Stager, R., *Centralbl. Bact.*, 1922, **2**, Abt., 56, 329–39. 2. Ocfemia, G. O., *Philip. Agric.*, 1931, **19**, 581–89.

OBSERVATIONS ON TWO MAMMALIAN COCCIDIA

IN June 1943, I found some fresh öocysts from the rectal contents of the rabbit *Lepus* sp. and the common Indian goat *Caprahircus* Linn.; both the hosts were collected from the suburbs of Calcutta. The öocysts of the rabbit when fully matured were found to be identical with *Eimeria stiedæ* (Lindemann, 1865), while those of the goat were found to be synonymous with *Eimeria faurei* (Moussu and Marotel, 1901).

E. stiedæ is being reported for the first time from India. *E. faurei*, though reported before from Indian sheep by Baldrey[1] (1906), the Indian goat *C. hircus* is added as a new host of this parasite.

The öocysts of *E. stiedæ*, measuring 30·2 — 37·4 μ by 22 — 26·4 μ, are ovoid in shape, light-brown in colour and flattened at one pole, as stated by previous workers. A micropyle is present at the flattened end of the öocysts. There is a well-defined spherical öocystic residual body about 1 μ in diameter. The sporocysts and the sporozoites have the same form and measurements as given by the previous authors. A residual body is also present in the sporocysts.

The öocysts of *E. faurei*, measuring 26·4 — 30·8 μ by 22-24·2 μ, are ovoid in shape and brownish in colour. There is a micropyle closed by a cap at one end of the öocyst. Wenyon[2] (1926) states that the öocystic residuum may or may not be present, but I could not find any öocystic residuum at any stage of development of the öocyst though a sporocystic residual body is present, as stated by him. A micropyle is present at the pointed end of each of the sporocysts and sporozoites have the same features as stated by previous observers.

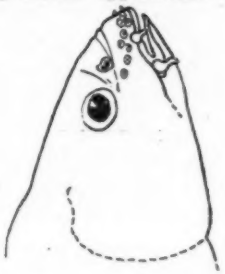
I am indebted to Mr. M. Chakraverty for his guidance and valuable suggestions and also to Prof. H. K. Mookerjee for kindly allowing me to work in this Laboratory.

Zoological Laboratory,
University of Calcutta,
July 24, 1943. AMIYA BHUSAN KAR.

1. Baldrey, F. S. H., *Jour. Trop. Vet. Sci.*, 1906, **1**, 387. 2. Wenyon, C. M., *Protozoology*, 1906, **2**, 830-844.

SEXUAL DIMORPHISM IN *SCHIZOTHORAX LONGIPINNIS* HECKEL

IN a collection of fishes made from the Dal Lake, Kashmir, in August 1938, there are numerous immature specimens of *S. longipinnis* Heckel, besides four full-grown specimens of the same species. Two of the four specimens possess smooth-skinned heads while the other two could be marked out by the presence of tubercles on the snouts and comparatively lean bodies. The tubercles are arranged in two groups, one on either side of the mid-dorsal line. On dissection it was found that both the smooth-skinned specimens are females possessing well-developed ova, while the tuberculated ones are males. The bigger male has 29 such tubercles while the smaller one possesses only 14. From the above observation it can be concluded that at the time of maturity the males of *S. longipinnis* develop "nuptial organs" which become more pronounced as the breeding season approaches.



Head of a ma'e specimen of *Schizothorax longipinnis* Heckel, showing tubercles on the snout. ca. Nat. size.

There does not seem to be any appreciable difference in the length of the fins in the two sexes. Since the specimens have been preserved in formalin, the exact coloration could not be noted.

The largest specimen in the collection is a male measuring 322·0 mm., while in female measuring only 249·1 mm. in length.

Department of Zoology,
Panjab University, NAZIR AHMAD.
October 26, 1943.

A PROBABLE INSTANCE OF RECAPITULATION IN DECAPOD LARVÆ

IN a paper published in 1937 on decapod larvæ from the Madras plankton[1] I had stated that the last two larval stages of *Albunea* possessed 12 and 13 gills respectively. Since the number in the adults is 10, I had ventured to state that this may be an instance of recapitulation of an ancestral character. Only two specimens belonging to the last stage were available at that time, so that the observation could not be confirmed then.

Recently I have been able to obtain several specimens belonging to both stages and on examination my previous observation has been found to be correct. It can, therefore, be definitely stated that the presence of a larger number of gills in these larvæ is a normal character and not an occasional abnormality.

In the corresponding stages of a closely related form, *viz.*, *Emerita*, the number of gills

is 8, one less than the adult number.[2] In other respects these larvæ resemble one another closely. The difference in regard to number of gills in *Albunea* larvæ may not, therefore, be correlated with any peculiarity in their habits. When it is remembered that the ancestors of both the Anomura and Brachyura are believed to have been forms with numerous gills there is very strong reason to assume that the larger number of gills of these larvæ is a clear case of recapitulation by the free-swimming larvæ of an ancestral character. It should therefore, be of considerable interest in view of the fact that recapitulation has generally been denied to occur among these larvæ.

Maharaja's College,
Ernakulam, M. KRISHNA MENON.
November 9, 1943.

1. *Bulletin of the Madras Government Museum*, New Series—Natural History Section, **3**, No. 5. 2. *Ibid.*, **3**, Nos. 3 & 4.

A NOTE ON THE OCCURRENCE OF CHLORITOID IN TUMKUR DISTRICT, MYSORE STATE

IN the course of a visit to parts of the Chitaldrug Dharwar Schist Belt in the Tumkur District, the writer came across a band of schist which contains the mineral chloritoid. As far as the writer is aware, there is only one reference to this mineral in the *Records of the Mysore Geological Department*. This is by the late Mr. B. Jayaram[1] who mentions the occurrence in the Hassan District, of "chloritoids" in the ultrabasic rocks north of Raipur, and of "a chloritoid mineral" in the hornblendic dykes north-west of Raipur. By the courtesy of Mr. B. Rama Rao, the Director of Geology in Mysore, the writer had an opportunity of examining microsections of these rocks referred to by Mr. Jayaram, but did not find any occurrence of chloritoid in them.

The exact locality where the chloritoid bearing schists are found is about two miles east-north-east of Banasandra railway station (on the Bangalore-Harihar Section), and about a furlong north-east of Lakkasandra village (1" topographical sheet No. 57 C/11).

The schist is greyish-green in colour, and when weathered has a dirty green colour which becomes brown in highly weathered specimens. Chloritoid occurs abundantly scattered in this rock, in disc-like, lenticular, or irregular shapes. The mineral is black in colour, and glistens brightly. The discs vary in diameter from 0·5 mm. to 2 mm.

The mineral has an almost perfect basal cleavage. Imperfect prismatic cleavages intersect at angles of 120°, and there is a parting parallel to 010.

Under the microscope, the schist is mainly composed of chlorite, sericite, and quartz. Grains of ilmenite altering into leucoxene are common. Crystalloblasts of chloritoid occur anyhow in the rock without any relation to the directions of schistosity. Crystals athwart the lines of schistosity are often seen to have pushed apart the flakes of chlorite and made room for themselves; this is because of the high force of crystallisation of chloritoid. The schistosity planes (represented by specks of ilmenite) are sometimes seen to pass right through the porphyroblasts of chloritoid. The mineral is poeciloblastic and contains abundant inclusions of quartz and ilmenite.

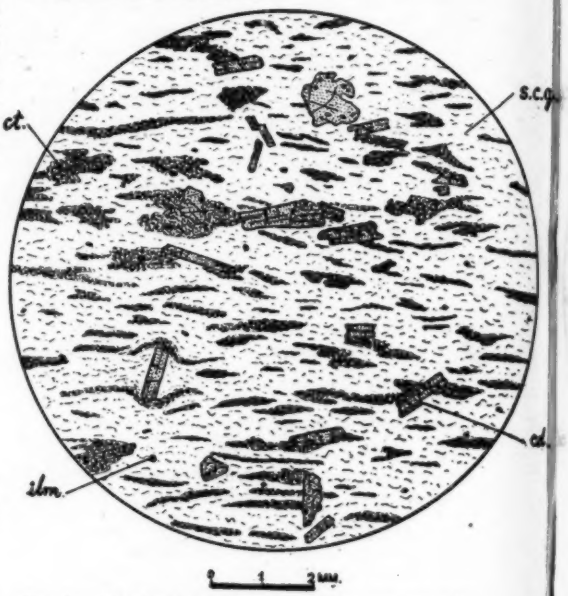


FIG. 1.—Chloritoid Schist, Lakkasandra, Tumkur Dist. *Cd.*—chloritoid. *Ct.*—chlorite. *s.c.q.*—sericite, chlorite, quartz. *ilm*—limenite.

The mineral is strongly pleochroic. The following is the pleochroic scheme: X = green, Y = indigo blue and Z = pale greenish yellow. The mineral has a high relief, but very low birefringence. The birefringence was measured by means of a Berek's compensator and the value obtained was $\gamma - \alpha = \cdot 009$ to $\cdot 01$. The direction Z makes an angle of 9° with the normal to 001. The optic sign of the mineral is positive.

Twinned crystals are common, the composition plane being parallel to 001. The composition plane is sometimes irregular.

Chloritoid is a typical stress mineral which is produced in a very low grade of regional metamorphism (epizone), though it is known sometimes to occur in the almandine zone.

The mineral is characteristic of sedimentary rocks which contain alumina in abundance and iron in sufficient quantities, and which are relatively poor in magnesia, lime, and potash. Its discovery, therefore, in the Dharwar schists of Mysore is interesting.

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December 8, 1943.

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THE CALCULATION OF THE CRITICAL SHEAR STRESSES AND THE SEDIMENT SIZES

THE writer[1] has recently worked out a theoretical solution of the critical shear stress, based on the assumption that the force impressed on a sediment layer by the moving fluid is proportional to the force exerted on the particles by their own weight, when falling freely in a stationary fluid column. The impressed force has been calculated from a consideration of the loss of momentum (Karman Theorem[2]) and for the stage of motion qualified as *general*, it has been deduced, provided the particles have the same fineness ratio, that

$$\tau_c/\rho_w V_s^2 = f(\rho_w U_{\tau_c} k/\mu) = F(\rho_w V_s k/\mu), \quad (1)$$

where

τ_c = critical shear stress at the stream bed $[M L^{-1} T^{-2}]$,

$U_{\tau_c} = \sqrt{\tau_c/\rho_w}$ = critical shear stress velocity at the bed $[L T^{-1}]$,

μ = fluid viscosity $[M L^{-1} T^{-1}]$,

ρ_w = fluid density $[M L^{-3}]$,

V_s = terminal velocity of the sediment particles $[L T^{-1}]$, and

k = particle diameter $[L]$.

These relations check well against observation and the solution of any relevant practical problem can be had from the two figures given in the paper cited.

However, in actual application, it is not possible to estimate the particle size, from a known value of the threshold shear stress, in a straightforward manner. Here, recourse must be had to the tedious process of successive approximations, and this, obviously, is very unsatisfactory. To overcome the difficulty, I suggest the following procedure.

It is easy to verify that

$$(\rho_s - \rho_w) g k \propto \rho_w V_s^2 \phi(\rho_w V_s k/\mu), \quad (2)$$

where ρ_s $[M L^{-3}]$ is the density of the sediment particles and g $[L T^{-2}]$ is the acceleration due to gravity. So making use of this, we are led from (1) to the result

$$\tau_c/(\rho_s - \rho_w) g k = f_1(\rho_w U_{\tau_c} k/\mu) = f_2(\rho_w^2 U^2_{\tau_c} k^2/\mu^2). \quad (3)$$

We multiply the respective coefficients in f_1 and f_2 by the left-hand side parameter $\frac{\tau_c}{(\rho_s - \rho_w) gk}$ and its reciprocal $\frac{(\rho_s - \rho_w) gk}{\tau_c}$, and so set up

$$\frac{\tau_c}{(\rho_s - \rho_w) gk} = f_3\left[\left(\frac{\rho_w}{\mu}\right) \frac{U_{\tau_c}^3}{(\rho_s/\rho_w - 1) g}\right], \quad (4)$$

and

$$\frac{\tau_c}{(\rho_s - \rho_w) gk} = f_4\left[\left(\frac{\rho_w}{\mu}\right)^2 (\rho_s/\rho_w - 1) g k^3\right]. \quad (5)$$

In these relations, the dependence of τ_c and k on $\tau_c/(\rho_s - \rho_w) gk$ is separately shown. It follows then from (4) that we need only know τ_c to calculate k, the numerical values of ρ_s, ρ_w and μ being given. For the estimate of τ_c, when k, ρ_s, ρ_w and μ are given, we normally use the result

$$\tau_c/\rho_w V_s^2 = F(\rho_w V_s k/\mu).$$

But consistent results are obtained, if the functional relation (5) is employed instead.

Also, the numerical estimate of k, for a given value of τ_c, or *vice versa*, can be made with equal ease and as readily, from a diagram, showing χ_1 plotted against χ_2, where χ_1 and χ_2 stand for the respective coefficients in f_3 and f_4. These parameters are plotted against one another in Fig. 1, $-\chi_1$ as ordinates and χ_2 as abscissæ.

The delineated curve is a good representation of the experimental spots. To the extreme left, the dotted portion is the one in better agreement with observation, though certain theoretical considerations demand it to be like the full line.

The annexe to the figure shows two experimental points by Dr. White,[9] along with some of the points from the main figure. Dr. White's investigation was with sand of mean grain diameter 0·21 mm. and 0·9 mm. respectively. Lubricating oil was used as the fluid, and steady viscous motion was maintained throughout the stream.

Through these points, a smooth curve has been passed, which, if put alongside the main curve, merges into it. This curve has a gentle declination, so much so, that the dotted straight line, whose equation is

$$U_{\tau_c} \cong 0{\cdot}464\left[\left(\frac{\mu}{\rho_w}\right)^{0{\cdot}24}\left(\frac{\rho_s}{\rho_w} - 1\right)^{0{\cdot}38} g^{0{\cdot}38} k^{0{\cdot}14}\right] \quad (6)$$

makes with the x-axis an angle of about 8° only.

On the other hand, the full curve (in the main figure) tends asymptotically, to the left, to a constant value. Its simple physical explanation is that, at low χ_2 values, the critical shear stress tends to be governed mainly by viscosity. Here the critical shear stress velocity equation reads

$$U_{\tau_c} \cong 0{\cdot}59\left[\left(\frac{\mu}{\rho_w}\right)^{\frac{1}{3}}\left(\frac{\rho_s}{\rho_w} - 1\right)^{\frac{1}{3}} g^{\frac{1}{3}}\right] \quad (7)$$

and holds for values of $\chi_2 \leqslant 275{\cdot}0$.

However owing to lack of sufficient experimental data, it is not possible to be quite definite about the shape to the left. To be able to decide whether or not the discrepancy between theory and experiment is real, we shall need further experimental evidence.

The main curve to the right rises off, at first slowly and then quite fast, the slope of

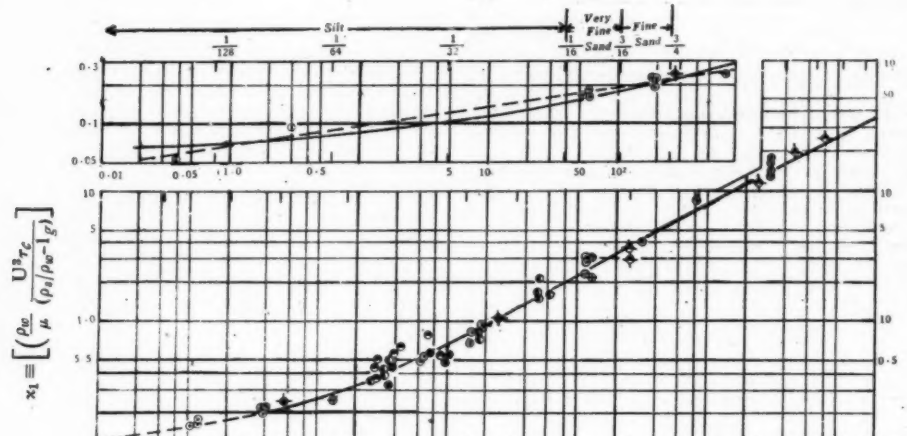

FIG. 1

Curve from which can be derived the value of k for a given value of τ_c or *vice versa*.

Observations of H. J. Casey[3] with uniform grains ⊙; of H. J. Casey[3] with mixtures ◐; of G. K. Gilbert[4] with uniform grains ⊕; of P. Y. Ho[5] with slaty mixtures ✦; of H. Kramer[6] with mixtures ●; of P. Srichamara[7] with uniform grains ✱; of the U. S. Waterways Experiment Station[8] with mixtures ◓; of Dr. C. M. White[9] with uniform grains Ⓓ.

the straight line to the right ($\chi_2 \geqslant 2{\cdot}25 \times 10^5$) being 26° 34′. Here the inertia terms become the predominant terms and the critical shear stress velocity is given by the formula.

$$U\tau_c \cong \frac{1}{4{\cdot}5}\left[\left(\frac{\rho_s}{\rho_w} - 1\right)^{\frac{1}{3}} g^{\frac{1}{3}} k^{\frac{1}{3}}\right], \qquad (8)$$

which does not contain the viscosity term, μ. This might have been foreseen.

In the range $275{\cdot}0 \leqslant \chi_2 \leqslant 2{\cdot}25 \times 15^5$, both viscosity and inertia terms affect the transport. But over the range $2{\cdot}25 \times 10^3 \leqslant \chi_2 \leqslant 2{\cdot}25 \times 10^5$, the coincidence of the curve with the straight line law (8) is quite close for most of the practical problems. And so, the application of (8) could be extended up to $\chi_2 \cong 2{\cdot}25 \times 10^3$.

Most of the practical problems concern sand of mean density 2·65 gm./cm.^{3} And so, assuming $\mu/\rho_w = 0{\cdot}01007$ cm.^{2}/sec. (corresponding to water temperature of 20° C) and $g = 981{\cdot}0$ cm./sec./sec., values of χ_2 have been calculated and the corresponding particle sizes (in mm.) are marked in the figure. This arrangement, it is hoped, will prove of aid in practice.

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October 11, 1943.

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REVIEWS

Time Bases (Scanning Generators). By O. S. Puckle, A.M.I.E.E. (Chapman and Hall, Ltd., London), 1943. Pp. 204. Price 16*sh.* net.

Time Base is the name given to those electrical devices or circuit arrangements which produce deflection potentials of suitable types for cathode-ray tubes as employed in the television or oscillograph techniques for visual observation of electrical phenomena. These potentials are made to vary at known rates with time and hence the modern name. For television purposes as also in many applications of the oscillographic work, the familiar "Saw-tooth" time base is employed in which the rate of change is made linear with time. In case of special kinds of oscillographic work electrical circuits have been developed giving potentials varying with time in a sinusoidal, circular, radial or spiral manner as the nature of the work demands.

Time base can aptly be described as the "brains" of the whole cathode-ray oscillograph outfit in that it decides how a recurrent electrical phenomenon will appear on the fluorescent screen. Its choice "may make all the difference between success and failure" as the author says in the introduction. In spite of the fact that developments on the time bases, trigger circuits, etc., have been largely responsible for the versatility of the cathode-ray oscillograph in its manifold uses, one does not find them adequately treated in any book published so far on the subject. Need, therefore, has keenly been felt for a unified treatment in one place of the underlying principles and commonsense involved in the design, construction and uses of such circuits. The book under review does more than fulfil this hope. In a series of enlightening chapters and appendices it gives a coherent account of the basic theory in the evolution and development of various kinds of time bases, their designs and modifications, etc., in proper historical perspective.

The book is divided into ten chapters and seven appendices. The reviewer feels that the scope of the matter covered by the book can be properly gauged by giving the chapter headings which run as follows:—

I. Introduction, II. Time base wave forms, III. Types of time base, IV. Trigger circuits, V. Blocking oscillators and inductive time bases, VI. Polar co-ordinate, multiple and velocity modulation time bases, VII. Linearization of the trace, VIII. Push-pull deflection, IX. The synchronization of time bases, and X. The use of a time base for frequency division.

For consistency of the treatment several important topics are dealt with in a series of appendices; they are vital to the main subject. For instance, a short description of the advanced aspects in the design of cathode-ray tube is given in Appendix I; the remaining six being devoted to, respectively, the curvature of the charging characteristic, the characteristics of a gas-discharge triode as a time base discharger valve, differentiating and integrating circuits, the generation of square waves, a method of changing the phase of a sinusoid and the effect of large shunt capacitances in the anode circuit of a valve.

A short bibliography and an index are given at the end.

A number of neat circuit diagrams and a few plates illustrate the volume.

The author who is a research engineer with Messrs. A. C. Cossor Ltd., London, is a well-known exponent of this art of electronic jugglery and is himself responsible for devising a few of these circuits; particularly, the hard valve time base which has extended the frequency limitations of the utility of the cathode-ray oscillatigraph from 50 kc./s. to 1000 kc./s. It is interesting to mention here that recent development of the deflection modulated type of tube, called the signal converter, is reported to have resulted in an all-round improvement in the cathode-ray tube performance.

The book is critically written—a virtue most essential to works of this type yet not often found. It essentially describes the technique as developed by the British with a few German and American circuits "thrown in" for the sake of completeness. It is free from misprints and errors. It is a fine example of its kind, authoritative, accurate and compact, but clear and cleverly written. The author has earned the gratitude of numerous workers in this field who will do well to assimilate the book rather than try to skim through.

It is indispensable to those interested in the electronic art and science. N. B. Bhatt.

Switchgear Practice. By Arthur Arnold. Chapman & Hall, Ltd., London), 1942. Pages 238 + iv. Price 22/-.

In recent years developments have been rapid and are still proceeding in almost every kind of switchgear, and a survey of practice, a sort of stock-taking as it were, is certainly useful from many points of view. This book by Mr. Arnold is a brief review of that kind and is, therefore, welcome. Again, consideration of switchgear enters into every industry and quite often engineers with very little or no experience in this field are called upon to deal with matters concerning its design, installation and operation. To them this book should serve as a useful guide as it enables them to some extent to appreciate aspects involved in the selection of switchgear.

The scope and aim of the book can be best understood by a perusal of the headings of the nineteen chapters into which the book is divided. They are: D.C. Circuit Breakers; Specialised D.C. Circuit Breakers; D.C. Motor Starters; D.C. Switch Boards; A.C. Circuit Breakers of Small and Medium Size; A.C. Motor Starters; A.C. Busbar Layout; A.C. Switchgear Types; Heavy Duty Circuit Break-

ers; Arc Control Devices; Isolation and Bus Selection; Methods of Circuit Breaker Operation; Interlocks; Switchgear Testing; Protective Devices on Switchgear; Instrument and Control Boards; Lightning Arresters; Fire Prevention and Protection; Oil-less Circuit Breakers. Each chapter is independent in itself and contains useful and up-to-date information on the topic selected. On account of the vastness of the field sought to be covered and the space limitations of a book of this size, rigid selection of the material is inevitable, but it can be confidently said that no material point has escaped notice. A comprehensive list of all relevant B.S.S. and a fairly representative bibliography on the subject given at the end of the volume, are useful additions.

S. KRISHNASWAMY.

Electrotechnics—*Journal of the Electrical Engineering Society*, Indian Institute of Science, Bangalore. Nos. 15 and 16, 1943.

We have received a copy of the current year's issue of this Journal. As the organ of the Electrical Engineering Society of the Indian Institute of Science, Bangalore, this Journal is known for the high standard of the articles published and we are glad to note that the issue under notice has maintained that standard. It contains thirteen well-thought-out articles of interest to the Electrical Engineering profession, mostly by Engineers with experience in the field they write upon. Editorial, Correspondence, Book Reviews, and News and Notes are among the other items.

It is a pity that no issue of this useful Journal could be brought out last year. We hope that its publication will go on uninterrupted from now on.

S. K. S.

The Carnivorous Plants. By Francis Ernest Lloyd. (Chronica Botanica Co., Waltham, Mass.; Calcutta: Messrs. Macmillan & Co., Ltd.), 1942. Pp. xvi + 352, 38 plates and 11 text-figures. Price $6.00.

The book under review, a monograph on the carnivorous plants, coming, as it does, from one who has devoted much valuable time in delving into the mysterious ways of the plants in question here, Prof. Francis Ernest Lloyd, Professor Emeritus in the McGill University, Canada, is an authoritative work, and its great usefulness to research workers in this field and to interested botanists in general must at once be recognised. Its appearance in print is most welcome, and Prof. Lloyd has spared no pains to make the account quite comprehensive and up-to-date.

Of the carnivorous plants, there are, excluding certain fungi, about 500 species representing fifteen genera of the flowering plants, and these fall into two groups, one under the Chloripetalæ, and the other under the Sympetalæ. Thus the peculiar and the very aberrant mode of nutrition exhibited by these plants must have been derived at least along two independent lines in the course of the phylogenetic history of the flowering plants.

The structural details exhibited by these plants and the exact mechanism involved in the capture and digestion of the prey are so many and so varied and complex, that it is hard to find one who could do justice to the subject other than the author himself. He classifies these plants into two major categories, the first where the traps are passive, with pitfalls, snares and fly-paper mechanism, and the second with active traps which display special movements necessary or contributory to the capture of the prey. In the different chapters of the book the carnivorous plants which come under these two groups are dealt with separately and in great detail.

In some, as in *Heliamphora*, *Darlingtonia and Pinguicula*, the digestion of the prey is brought about by bacteria contained in the pitcher fluids, whereas in a few others, as in *Sarracenia* and *Cephalotus*, the digestion is mainly due to the secretions from the glands, although bacteria may aid to a certain extent. In *Nepenthes* there are two enzymes—a catheptic and a tryptic—concerned in digestion, but there are also large numbers of bacteria in the pitcher fluid and these may only play a very secondary role.

After giving a resumé of the several interpretations regarding the morphology of the pitcher leaves in *Nepenthes*, Prof. Lloyd draws attention to the many interesting structural features of the pitchers and their role in ensnaring the unfortunate victims. And here it is interesting to refer to his observations. The insects walking on the lid of the pitchers run no risk of capture. "On the rim", however, it is supposed that they do. As a matter of fact, however, they do not, for they walk on it in any direction with rapidity, and they frequently stop to take the nectar from the marginal glands. They even passed underneath the rim and back several times in one excursion without danger. If, however, they venture on to the waxy zone they at once display a quite different behaviour. They cannot then by any chance move rapidly forward. If they progress at all, it is very slowly and with much groping with the legs as if searching for a hold. Usually this results in a complete loss of the foothold, and the ant falls into the abyss."

There are various associates which the pitchers harbour, and it is interesting to note that these constitute a "terrestrial fauna" above the level of the fluid, and an "aquatic fauna" in the fluid.

The eel-traps of *Genlisea* are remarkable for their structural complexities, and there is a good deal of speculation regarding the function of the glands here. They may secrete mucilage to facilitate passage of the prey down the trap, or they may secrete digestive enzymes, or both. Bacterial action may not, however, be completely excluded in digestion. In both *Dionœa* and *Aldrovanda* which display the steel-trap mechanism the mode of capture of the prey is essentially similar and digestion is due to the secretions by the glands found on the inner surfaces of the traps.

In the chapter on *Drosera*, the phenomenon of aggregation in stimulated tentacles is fully

dealt with and the cytological and physiological complexities involved in the process of digestion are discussed in detail. After reading through this chapter the reader is brought to the realization of the fact that the whole process of digestion in *Drosera* is not, contrary to what one learns from the usual accounts, a simple one. Prof. Lloyd points out the many-sided interest of this problem, and emphasises the need for further work in this promising field.

By far the most wonderful of the carnivorous plants is *Utricularia* belonging to the family Lentibulariaceæ. In this family we find examples of the simplest traps (*Pinguicula*), the most complex of the pitfall type (*Genlisea*), and the incomparable trap of *Utricularia* itself. Prof. Lloyd compares the trap of *Utricularia* to a mouse-trap, not the ordinary simple dead-fall one, but an elaborate, automatic, self-setting mouse-trap which catches as fast as the victims come, and which is provided also with a disposal plant so that nothing is left at last but hair and bones, the trap working in any position and even under water. This analogy may be rather far-fetched, but as Prof. Lloyd remarks, it at least serves to indicate that the *Utricularia* trap is a pretty complex bit of mechanism.

While ordinary accounts of the carnivorous plants do not include the fungi which prey on animalcules, a chapter in the present book is devoted to the zoophagus fungi. It is interesting to read how uncanny these fungi are and what diabolical methods they employ in capturing their victims.

The origin and evolution of the carnivorous plants are some of the interesting questions that arise in the minds of interested readers, but unfortunately little can be said in answer to them, and as Prof. Lloyd says, how these specialised organs of capture in these plants could have evolved defies our present knowledge.

All students of botany interested in this subject will be sure to have nothing but praise for the book, and gratitude to the author for making his extensive and intimate knowledge of these plants available to a very large circle of readers. Throughout the book the language is simple and lucid, and the style thoroughly enjoyable. The book is profusely illustrated with numerous photographic reproductions and excellent line drawings, many of them prepared by Prof. Lloyd himself. The usefulness of the book is further enhanced by the incorporation under different chapters of all the original and up-to-date literature in this field.

The get-up of the book leaves nothing to be desired, and the price is quite modest. Considering the present difficulties due to war, the publishers deserve our warmest congratulations for bringing out this volume, the ninth in the new series of plant science books under the editorship of Dr. Frans Verdoorn. This book is an outstanding contribution to botanical science by Prof. Lloyd and ought to find an important place in every botanical and general science library.

S. B. KAUSIK.

Indian Village Health. By J. N. Norman-Walker. (Oxford University Press, Madras), 1943. Pp. 90. Price Rs. 2-8-0.

In this small book, the author has made an attempt to deal with most of the important health problems affecting Indian village life. General principles in the handling of the common Communicable Diseases have been dealt with. Local experience seems to have unduly influenced some of the observations of the author and several of the detailed recommendations under Malaria, Small-pox, Water and Milk have been superseded by more up-to-date practices.

The absence of stress on the importance of grain movements as a major source of spread of plague and the necessity for early diagnosis of cases of Tuberculosis are serious omissions. The use of copper-sulphate for destroying harmful organisms in water is limited to the prevention of objectionable algæl growths only.

The brief notes given under Appendix is helpful for the field worker in Public Health. The few model plans included at the end of the book, are useful in designing construction of public utility.

B. ANANTHASWAMY RAO.

An Introduction to Historical Plant Geogrphy. By E. V. Wulff. (Waltham, Mass.: The Chronica Botanica Co.; Calcutta: Macmillan & Co., Ltd.), 1943. Pp. 223. Price $4.75.

The book gives a fascinating account of the History of Plant Geography. As is usual with the Chronica Botanica publication series, the book is written by an acknowledged authority and includes most of the works of the author himself. The entire work is divided into eleven chapters and embraces all aspects of plant geography. It will be noticed that every advance in the field of Botany has some bearing or the other on the study of plant geography.

It is not possible within this short space even to review the wealth of facts presented in the book. But a very brief account of the subjects treated therein might not be out of place. But one must certainly go through the accounts given in the book to get a proper perspective of the importance of the study of plant geography.

The region of distribution of any taxonomic unit which is termed an area, might be natural, or artificial by intentional or accidental introduction by man. The topography which is affected by physico-geographical conditions is often made difficult to be comprehended on account of inherent peculiarities of the plants themselves. Some are stenothermic (growing within certain restricted temperatures), others require mycorrhiza for their growth or even a particular type of insect visitors. The latter forms are usually termed stenotopic.

Regarding areas and their distribution, a detailed account of the present status of the "age and area" hypothesis is given. It is well known that the centre of an area for a parti-

cular genus, is the place where there are the maximum number of its species. Regarding the endemics, based on the floristic studies of Ceylon and New Zealand, Dr. Willis concludes that the endemic species which occupy the smallest areas in those islands are young, and that the area of the species is proportional to age. As Dr. Wulff has pointed out, this does not explain the cases of endemics which have acquired their monotypic character as a result of the dying out of most of their species. Endemism might be the result of taxonomic isolation, in which case it might be young, as compared with the endemics which manifest phylogenetic antiquity. Various terminologies to differentiate the two types, including the use of the terms, neoendemics and palæoendemics, are given.

A discussive account of various species and their possible origin due to edaphic factors is given. The importance of plant rusts and plant lice in gleaning out the facts about past distribution of plants is finely illustrated. This indirect method of study is useful where evidences from fossil records are lacking.

In the chapter on artificial factors in the geographical distribution of plants, the role of man in distributing and changing vegetation is pointed out. Considering the vastness of the flora, man's part is insignificant in changing the character of an area.

Referring to natural factors concerning geographical distribution of plants, such as wind, importance of competition among plants to inhabit new areas, or between the new comers and those already present is stressed. The necessity of understanding the past history of the globe to explain discontinuous distribution is explicitly stated. In this connection a comprehensive account of Wegener's theory of Continental drift as supported by phyto-geographical studies is given. Diel's criticism of Wegener's hypothesis is shown to be not in keeping with facts. In the last chapter concepts of floral elements such as geographical, ecological and historical elements are elegantly described. The book is a very valuable addition to the Chronica Botanica series and must have a wide circulation it deserves.

M. J. THIRUMALACHAR.

SCIENCE NOTES AND NEWS

On the Production of Carbarsone.—Mr. A. K. Bose, of the Indian Research Institute, Ltd., Calcutta, writes:—Carbarsone, the carbamido derivative of arsenilic acid, is one of the most innocuous of the organic arsenicals. Its amœbicidal action is directly connected with its arsenic content. Theoretically it contains 28·8 per cent. arsenic; but as the drug is being marketed in tablets and gelatin capsules containing 0·25 gm., it is of special importance to see that its content of arsenic as demanded by the above amount of the drug, is strictly maintained. The arsenic content of "Carbarsone" usually available in the market is sometimes found to be lower than the standard (28·1 to 28·8 per cent.).

The compound has now been prepared in this laboratory and has been found to be upto standards and specifications as mentioned in the *New and Non-official Remedies*, 1939. The product melts at 172° with decomposition and the arsenic content as determined by the U.S.P. XI method has been found to be 28·7 per cent. in average, indicating thereby, that a technique of producing carbarsone with arsenic content just within the limit as specified in the N.N.R. has been developed in the country.

Post-War Agricultural Policy in India: Planning for Self-Sufficiency in Manurial Requirements.—Dr. C. N. Acharya writes:—One of the bitterest lessons taught this country by the present war is the great weakness in the national economy in having to depend on imports from foreign countries in order to meet the normal food requirements of the country. A searching analysis of the failure of the country in recent decades to meet the food requirements of its increasing population, shows this failure to be due ultimately to the low fertility level and crop-yielding power of Indian soils. In any post-war agricultural policy, a systematic planning for improving the fertility status of Indian soils should occupy the most prominent attention. Such planning would envisage primarily the production and application of greater quantities of fertilizers and manures to the land than are done at present.

In considering various methods of tackling the manurial problem, weightage should be given to a policy which would stand the stress of prolonged war conditions. Dependence on imports of fertilizers for maintaining food production in the country is no sounder policy in war time than dependence on imports of food materials themselves. So far as India is concerned, her local resources of mineral phosphates are limited and in the matter of nitrogenous fertilizers, her internal production is also low at present. Even supposing that the production of nitrogenous fertilizers by fixation from the air could be increased greatly after the war, it is well known that most of this production would be diverted for the manufacture of explosives in war-time.

In the light of the above considerations, it would be seen that the soundest policy to be adopted in our post-war agricultural reconstruction in India would be to concentrate on increasing the quantity and quality of organic manures that could be produced within the country itself.

The two chief sources of organic manure that are available in this country are farmyard manure and town refuse compost—the quantities of oil-cake, fish meal, etc., available being quite small in comparison. Farmyard manure has been the staple manure of this country for centuries past, but unfortunately it is unable to satisfy in full the present manurial requirements of our agriculture, since (*a*) the quantity of farmyard manure produced is much smaller than what could be made available from a bovine population of over 200 millions maintained in this country, on account of the widespread custom of our farmers, of converting cattle dung into fuel cakes; (*b*) the quality of the manure produced is very poor on account of defective methods of preparation; (*c*) the most important constituent of animal excreta, *viz.*, urine, is almost wholly wasted under existing conditions; and (*d*) the miscellaneous odds and ends of vegetable and habitation refuse that are available on the farms and in farmers' houses are not systematically collected and utilized for manure preparation.

The experiments and trials carried out by the writer at Bangalore, Poona, Surat and other centres, have shown that the quantity of farmyard manure that could be prepared can be increased by 50 per cent. and the contents of nitrogen and phosphoric acid could be increased from 0·5 per cent. and 0·3 per cent. respectively (on dry basis) on average samples by the farmer's method to about 1·5 per cent. and 0·8 per cent. respectively by the improved method.

The practical possibility of utilizing town wastes on the large scale for conversion into agricultural manure has attracted the attention of the Government of India, who have recently sanctioned a special grant for organizing the preparation of compost manure from municipal wastes in all the major Provinces and States in India. Under this scheme, which is operated by the Imperial Council of Agricultural Research, Special Biochemist Officers have been appointed in the major Provinces and States in India, with necessary staff for organizing compost production work at urban centres in their respective areas. The above Biochemist Officers have undergone intensive training in the theoretical and practical aspects of compost making for a period of six months under the guidance of the Chief Biochemist to the Imperial Council of Agricultural Research.

It is suggested that the staff of Compost Biochemists and Assistant Chemists already appointed in each Province, primarily for dealing with town wastes, may be more fully utilized by empowering them to take into their purview the problem of introducing improved methods, of farmyard manure and farm compost preparation into the rural areas in their respective Provinces and States; and that for this purpose the present staff may be strengthened by the appointment of a number of Compost-Khamghers or Maistries attached to each Assistant Chemist, who would specifically deal with the widespread introduction of the improved process for the treatment of farm wastes in rural areas.

India's Mineral Industries.—In the course of his Presidential Address to the Nineteenth Annual Session of the Geological, Mining and Metallurgical Society of India, held on the 29th November 1943 at Calcutta, Mr. B. Rama Rao stated that the estimated value of India's annual production of ores, minerals and metals has been ranging now from 30 to 35 crores of rupees, which, when compared with the value of minerals, metals and mineral fuels produced annually in the United Kingdom, South Africa, Canada and Australia, stands lowest. The progress of mineral industries in India during the last fifty years, though not altogether negligible, cannot be considered to be commensurate with the country's extent and of its total population. Lack of enterprise and initiative on the part of the Indian capitalists have been responsible for this slow progress. State-guidance and Government help have not been forthcoming in as generous a measure as would be effective; the country's general ignorance of its available mineral resources and their uses is also a contributory cause.

India's present imports of various mineral products, mineral fertilisers and chemicals, etc., amount to several crores of rupees every year. Most of these,—like refined kaolin, dressed emery, graded asbestos, and industrial chemicals like the dichromates, can be easily prepared in India out of the raw minerals available in the country.

Mr. Rama Rao said that India has deposits of more than a hundred varieties of useful minerals which could serve as raw materials for several industries, but these are, however, irregularly distributed in the country. For the development of mineral industries in any part easy accessibility to the requisite mineral deposits is necessary. While some parts like Bihar and Orissa, and Southern India have a multitude of useful minerals, others like Bombay, Baluchistan and Rajputana have but a few worthy of note. After giving a succinct account of the provincial distribution of minerals and the mineral industries now existing therein, he examined in detail the scope for expansion of the metallurgical industries like iron and steel smelting, production of ferro-alloys, extraction of gold, lead, and copper, etc., and also the scope for developing various non-metal industries—like the manufacture of abrasive products; ceramic, refractory, and glass industries; mineral paints and pigments; and production of mineral fertilisers and chemicals.

Reliable information on the extent and quality of most of the deposits, in several areas, was lacking and this could be obtained only by an intensive mineral survey of each of the provinces by modern methods of prospecting. But the geological service now available for such a task was absolutely inadequate. It should be the primary function of the State to foster the rapid growth of the country's mineral industries. Mr. Rama Rao strongly urged (1) the organisation by Government of well-equipped mineral survey departments in each of the provinces, and (2) the constitution at the Centre, of a "National Mineral Utilisation Board" with several

advisory committees in respect of different groups of industrial minerals.

Indian Patents.—Mr. S. G. Sastry, B.A., M.Sc. (Lond.), Director of Industries and Commerce (Retired), writes to us as follows:—

Recently I had occasion to have some correspondence with the Controller of Patents in Calcutta on a matter of some importance to Indian scientific workers. My correspondence with the Controller of Patents and Designs referred to a particular type of sulphur burner which had been described in the *Chemical and Metallurgical Engineering of New York*. Whether the process or the apparatus already described in current technical literature which had already been patented in foreign countries could be given patent rights in India was the main issue raised by me. The Controller of Patents has given a ruling on this subject, and further he has permitted me to quote the relative portions from his letter on the subject. It is this official ruling given by the Controller of Patents that is of some importance to scientific workers in India. "... The second question is 'can any one apply for a patent if a particular invention or if a particular process which is known in other countries happens to be either unknown or little known in British India?' The answer to this question is that prior knowledge or prior use of an invention outside British India is not a bar to the grant of a patent in British India if the invention has not been publicly used or publicly known in any part of British India, prior to the date on which the application for a patent was made in this counery. An invention is deemed to be publicly known if a document containing an adequate description of it, whether issued as a general publication or not, has in the course of ordinary business and without imposing any secrecy, reached an appreciable section of the public interested in the art to which the invention relates."

Administration Report of the Government Mineralogist for 1942, Ceylon, Part II—Revenue (1).—This Report which covers some six pages of close printing, deals with the usual activities of the Department during the year.

A new mining ordinance has been introduced to improve mining conditions. Though a lot of difficulty was felt, the production of graphite has considerably increased. To encourage exploitation, the Royalty on mica has been reduced from 5 to ¼ per cent. A new welcome feature of the Department is the starting of publication of professional papers on various topics concerned with the Geology and Mineralogy of Ceylon. The Government have also started to record scientifically the fall of meteorites and to preserve them in the State museum.

On the economic side investigations on Peat tracts are progressing and more information is available on the vanadium-content of the ilmenite sands. Kaolin can be worked if a market is found for it outside Ceylon, and the occurrence of Copalite resin offers an incentive for the development of a new industry. The iron ore deposits of Ceylon have been estimated as sufficient to last the country for about a century.

Geological survey of small areas is proceeding, and the relationship between the major formations of Ceylon is becoming more and more clear. B. V. I.

The Geological, Mining and Metallurgical Society of India: Elected Council for 1943-44.—*President*: Sir Cyril S. Fox; *Vice-Presidents*: (1) Prof. L. Rama Rao, (2) Prof. N. N. Sen; *Joint-Secretaries*: (1) Prof. N. N. Chatterjee, (2) Prof. S. K. Bose; *Treasurer*: Prof. B. N. Maitra; *Librarian*: Prof. S. Ray; *Other Members of the Council*: (1) Prof. M. Chatterjee, (2) Dr. A. K. Dey, (3) Prof. T. N. Muthuswamy, (4) Mr. P. S. Narayana, (5) Mr. N. H. Ojha, (6) Mr. N. L. Sharma, (7) Prof. Daya Swarup, (8) Prof. K. P. Rode.

SEISMOLOGICAL NOTES

Among the earthquake shocks recorded by the seismographs in the Colaba Observatory, Bombay, during the month of September 1943, there were four of moderate and four of slight intensities. The details for those shocks are given in the following table:—

Date	Intensity of shock	Time of origin I.S.T.	Epicentral distance from Bombay	Co-ordinates of epicentre (tentative)	Depth of focus	Remarks
		H. M.	(Miles)		(Miles)	
5	Moderate	15 05	3540	Lat. 5° N., Long. 125° E., near Mindanao.	..	Probably slightly deep.
6	Moderate	10 12	7070	..	90	..
9	Slight	10 36	1310	..	170	Epc.: Hindu-Kush. Felt at Rawalpindi, Muzaffarabad, Dera Ismail Khan, Gauhati, Kabul, Drosh, Gulmarg and Srinagar.
10	Moderate	15 07	3950	..	..	..
14	Slight	08 31	7180	..	..	..
14	Slight	10 13	7110	..	..	..
14	Slight	13 56	5290	..	..	..
24	Moderate	18 01	1190	Lat. 37° N., Long. 74°·5E., near the Hindu-Kush mountains	..	..

Among the earthquake shocks recorded by the seismographs in the Colaba Observatory, Bombay, during the month of October 1943, there were one of great, one of moderate and five of slight intensities. The details for those shocks are given in the following table:—

Date	Intensity of shock	Time of origin I.S.T.	Epicentral distance from Bombay	Remarks
		H. M.	(Miles)	
1	Slight	13 01	1370	..
5	Slight	17 41	1610	..
10	Slight	07 13	1360	..
22	Moderate	22 31	3110	..
23	Great	23 54	1290	Epicentral region in Assam. Reported to have been felt in some places in Assam and North Bengal.
24	Slight	20 11	4890	..
24	Slight	22 34	8330	..

MAGNETIC NOTES

Magnetic conditions during November 1943 were slightly less disturbed than in the previous month. There were 10 *quiet* days, 18 days of *slight* disturbance and 2 days of *moderate* disturbance as against 17 quiet days and 13 days of slight disturbance during the same month last year.

The quietest day during November 1943 was the 11th and the day of largest disturbance the 19th.

The individual days during the month were classified as shown below:—

Quiet days	Disturbed days	
	Slight	Moderate
2–4, 9, 11, 13–15, 17, 30.	1, 5–8, 10, 12, 16, 18, 21–29.	19, 20.

No magnetic storm occurred during the month of November in the years 1942 and 1943.

The mean character figure for the month of November 1943 was 0·73 as against 0·43 for November 1942. M. V. SIVIRAMAKRISHNAN.

We acknowledge with thanks the receipt of the following:—

"Journal of the Royal Society of Arts," Vol. 91, Nos. 4644, 4648, 4650.

"Journal of Agricultural Research," Vol. 67, Nos. 1, 2 & 4.

"Agricultural Gazette of New South Wales," Vol. 54, Pt. 10.

"Biochemical Journal," Vol. 37, No. 3.

"Central Board of Irrigation Bulletin," No. 41 (Sep. 1943).

"Journal of Chemical Physics," Vol. 11, No. 9.

"Experiment Station Record," Vol. 89, Nos. 2-3.

"Indian Farming," Vol. 4, No. 6.

"Indian Forester," Vol. 69, Nos. 11-12.

"Bulletin of the Indian Central Jute Committee," Vol. 6, Nos. 7-8.

"Indian Medical Gazette," Vol. 78, Nos. 10 and 11.

"American Meteorological Society Bulletin," Vol. 24, No. 4.

"Review of Applied Mycology," Vol. 22, No. 8.

"Journal of Nutrition," Vol. 26, No. 2.

"Nature," Vol. 152, No. 3859.

"Science," Vol. 98, Nos. 253-39.

"Science and Culture," Vol. 9, Nos. 5-6.

"Journal of Scientific and Industrial Research," Vol. 2, No. 1.

"Monthly Science News," No. 25.

"Sky," Vol. 2, No. 11.

"Indian Trade Journal," Vol. 151, Nos. 1947-1953, 1955.

BOOKS

An Introduction to the Modern Theory of Valency. By J. C. Speakman. (Edward Arnold & Co., London), 1943. Pp. 159. Price 5/6.

ERRATA

"Coconut Shells as an Industrial Raw Material: I. Composition of Shells".—Vol. 12, p. 292, in the table *for* "SO_2" *read* "SiO_2"; p. 292, para (iii), Organic Constituents: line 2, *for* "W. L. Winton" *read* "A. L. Winton"; line 5, *for* "species" *read* "spices".

"The Origin of Rohr at Didwana".—Vol. 12, p. 295, para 3, line 3, *for* "months" *read* "weeks"; p. 297, Table III, Raw Brine, NaCl : Na_2SO_4, col. 3, *for* 2·8°:1 *read* 22·82 :1.

SUPPLEMENT TO CURRENT SCIENCE

Vol. XII] DECEMBER 1943 [No. 12

THE FUNDAMENTALS OF CRYSTAL PHYSICS*

By SIR C. V. RAMAN

THE crystal is Nature's most highly finished product in the field of atomic architecture. The majority of solids we handle in our daily lives are crystals by virtue of their structure, and their behaviour is largely determined by the properties of the crystalline state of matter. The fundamental aspects of crystal physics may, therefore, be of interest to many who are not professional physicists and I feel justified in making them the subject of my address to-day. I will leave it to my friend and colleague, Dr. Birbal Sahni, to voice the appreciation by our Fellows of the kindness and hospitality of our Hyderabad friends which has made our meeting here together in these difficult days possible.

* * *

As is well known, the study of the beautiful external forms exhibited by well-developed crystals enables them to be grouped into classes exhibiting specific types of geometric symmetry. One of the most firmly established results of crystal physics is the existence of fundamental relationships between these symmetry classes and the various physical properties which the crystals belonging to them exhibit. Indeed, if the symmetry of the crystal is known, the branch of mathematical analysis known as group theory enables us to predict the general nature of its behaviour in respect of any specified physical property. By way of illustration, I may refer to a recent paper by Principal Bhagavantam in our *Proceedings*, in which he has discussed the elastic, optical and elasto-optic properties of different crystal classes and corrected the results obtained earlier by Pockels. The existence of such relationships is a natural consequence of the fact that a crystal is essentially an ordered arrangement of the ultimate particles of matter in a regular geometric pattern. Crystal architecture is based on the space-lattices which are formed by three sets of parallel and equidistant planes in space intersecting each other at a set of points which form a three-dimensional net or repetitive pattern. Each point of the lattice is occupied by an atom of the same kind, and all the atoms in the lattice are, therefore, equivalent. The simplest crystals consist of a single space-lattice and contain only one species of atom. More complicated crystals contain two, three or more sets of equivalent atoms, the space-lattices occupied by the different sets being geometrically similar and similarly situated, but not coincident. In other words, a crystal contains as many similar interpenetrating space-lattices as there are sets of equivalent atoms in it.

It is obvious, however, that a purely static conception of crystal architecture is inadequate. We must consider also the possible movements of the atoms away from the lattice points at which, on the average, they are placed. The importance of ascertaining and describing the atomic movements cannot be overemphasised. The thermal energy in a crystal is essentially the mechanical energy of such movements, and the thermal agitation of the atoms determines or modifies practically every observable property of the solid. Further, the amplitudes and frequencies of the possible atomic vibrations are determined by the forces which hold the atoms together in the form of a coherent solid. Hence, a knowledge of the atomic vibration spectrum of the crystal is essential for an understanding of its ultimate structure and indeed also of all the properties characteristic of the solid state. It is, therefore, necessary to find an answer to the question, what are the modes and frequencies of the possible vibrations of the atoms in a crystal about their positions of equilibrium in the space-lattice?

There are two ways in which an answer has been sought to this question. One way is to take the well-known theory of the vibrations of an elastic solid as the starting point and extrapolate it to the very limit. For this purpose, it is assumed that the atomic vibrations which occur on an extremely minute scale and as rapidly as a hundred or a thousand million times per second are determined by the same principles and considerations as are the visible and audible vibrations of a bell or a tuning-fork. It may be questioned whether such an extrapolation from macroscopic to molecular physics is theoretically justifiable. The other approach to the problem is the atomistic one. We fix our attention on the individual atoms located at the points of the space-lattice and ascertain the forces which come into play when they are displaced from these positions and calculate the resulting movements. It is obvious that the atomistic approach is the more reasonable one in dealing with vibrations of very high frequencies, and that it is much more likely to give us the correct results.

* Presidential Address to the Indian Academy of Sciences at its joint meeting with the National Academy of Sciences at Hyderabad, 26th December 1943.

The immense numbers of atoms involved and the complexity of the structure of many crystals might suggest that the atomistic approach to our problem would be a formidably difficult one. Actually, however, this is not the case. A very great simplification is introduced by the fact that all crystals consist of a finite number (in many cases quite a small number) of sets of equivalent atoms. Equivalent atoms have the same mass and occupy equivalent positions in the structure of the crystal. They are held in their respective environments by equivalent force-systems. In any particular mode of vibration, all the atoms must oscillate with the same frequency and with either the same or the opposite phases everywhere. The forces acting on any given atom are determined by its own displacement and by the displacements of the atoms forming its environment. These factors in the problem result in a severe restriction of the possible modes of atomic vibration. It is easily seen that the conditions stated can only be satisfied if the resultant force acting on an atom and its consequent displacement have the same magnitude and either the same or the opposite phase as the corresponding quantities for every other equivalent atom. This again is only possible if the amplitudes and phases of atomic vibration repeat themselves in a space-pattern of which the units have twice the linear dimensions and, therefore, eight times the volume of the unit cell of the crystal lattice. This doubling of the scale of the vibration pattern as compared with the static structure of the crystal is a direct consequence of their being two possibilities for the relative phases of the movements of neighbouring equivalent atoms in the crystal, namely, that they may be either the same or the opposite of each other.

The atoms whose movements describe the possible modes of atomic vibration are thus eight times as many as those included in the unit cell of the crystal lattice. Multiplying their number by a factor of three representing the degrees of freedom of movement of each atom, and subtracting from the total, the three possible movements of translation of the entire group, we get $(24p - 3)$ as the number of its possible internal modes of vibration, p denoting the number of sets of equivalent atoms in the crystal. Of this total, $(3p - 3)$ vibrations are movements of the various interpenetrating lattices of atoms as a whole with respect to each other, while the remaining $21p$ vibrations are oscillations in which the alternate planes of equivalent atoms in the crystal oscillate against each other. These numbers are very greatly reduced when the crystal possesses a high degree of symmetry, as for instance, when it belongs to the cubic, tetragonal or hexagonal class, several of the possible modes of vibration then becoming identical. The existence of symmetry also enables us in many cases to specify the directions of movement of the atoms in the crystal. A complete enumeration and geometric description of the various possible modes of vibration is, in fact, possible in the case of crystals of high symmetry and of not too complicated a structure.

The ideas and results briefly outlined here are elaborated and applied to several different crystal structures in a symposium of papers published as the November 1943 issue of the *Proceedings* of the Academy. Taking, for instance, the cases in which the crystal contains only one species of atom, Mr. G. N. Ramachandran has systematically dealt with all the fourteen possible space-lattices in turn, and showed how the number of possibilities diminishes from the 21 modes of vibration with unspecifiable directions for the triclinic lattice to the four modes with completely defined directions of the face-centred and body-centred cubic lattices. The cases of various structure types in the cubic system, *e.g.*, rock-salt, zinc blende, flourspar and cæsium chloride, have been discussed by Mr. E. V. Chelam both by purely geometric and by group-theoretical methods. The application of the analytical methods of the group theory to the problem has been considered in the symposium from two different points of view. One way is the application of the standard group-theoretical methods to the enlarged space-unit containing eight lattice cells. The other is to start with each of the eight possible classes of vibration for the unit cell of the crystal lattice shown to be possible by the dynamical theory and consider them in turn. It is very gratifying that the results obtained by Professor Bhagavantam and Mr. Chelam respectively by the two methods in the case of diamond are completely identical. They show that the diamond structure has eight fundamental frequencies of vibration, of which the highest represents an oscillation of the two interpenetrating lattices of carbon atoms against each other. Their theoretical investigations enable us to understand the very striking experimental results obtained by Nayar in his studies of the luminescence and absorption spectra of diamond at low temperatures, as also the experimental findings of Dr. R. S. Krishnan in his recent investigations on the scattering of the 2,537 mercury radiations in diamonds of the ultra-violet transparent type.

Considered broadly, the results of the present theory form a striking and even startling contrast with those generally believed in at present. We see that the atomic vibration-spectrum of a crystal is essentially discontinuous and exhibits a finite set of discrete monochromatic frequencies, which are the more numerous, the more complicated the structure of the crystal is and the lower its symmetry. This picture bears no resemblance to the older ideas of the vibration spectrum of a crystal suggested by an extrapolation from the theory of the elastic vibrations of a solid. Such extrapolation into the region of atomic vibration frequencies is the basis of the well-known theory of specific heats of solids due to Debye; it yields an immense number of frequencies forming a continuous spectrum, in which the modes of vibration aggregate more densely together as we approach the high-frequency limit assumed in the theory. The Born crystal dynamics also yields a continuous spectrum of vibration frequencies as the result of the assumption on which it is based, namely, the Born-Karman boundary conditions, also known as the postulate of the cyclic lattice. The difference between the results of the new

crystal dynamics and of the existing theories is so great that the issue between them ought to be capable of settlement by a direct appeal to the experimental facts. The relevant spectroscopic evidence has been marshalled in two reports by Dr. R. S. Krishnan and by Mr. D. D. Pant, dealing respectively with the scattering of light in crystals and with their luminescence spectra and the associated absorption spectra at low temperatures. As will be seen from the reports, these three entirely independent groups of experimental studies furnish a great mass of unequivocal and by reason of their concurrence, overwhelming evidence that the vibration spectra of crystal lattices consist of discrete monochromatic frequencies which under ideal conditions, *e.g.*, at low temperatures, are quite as sharply defined as the vibration-frequencies of a gaseous molecule.

The failure of the Born dynamics to explain the observed facts is perhaps most clearly evident in the very case which has been most exhaustively discussed by Born and his collaborators, namely, rock-salt. The vibration-spectrum of the sodium chloride structure has been worked out on the basis of the Born postulate by Kellermann, and is a continuous one with three very broad and diffuse humps or intensity-maxima. On the other hand, in the present theory, the structure has one discrete frequency of vibration representing the oscillation of the sodium and chlorine lattices against each other, and eight other discrete frequencies representing oscillations of the layers of atoms parallel to the cubic and the octohedral planes alternately against each other in specifiable directions. On account of the symmetry of the atomic arrangements in the crystal, all the nine frequencies are inactive as fundamentals in light-scattering. The theory, however, indicates that all the nine frequencies may appear as octaves in the spectrum of the light scattered by the crystal. As long ago as 1931, using the 2,537 radiations of the mercury arc, a large clear rock-salt crystal, and prolonged exposures, Rassetti obtained a very beautiful spectrogram and microphotometric record. This appears very clearly reproduced in Fermi's book of 1938 entitled *Molekule und Krystalle*. Fermi himself admitted his inability to offer any explanation for the features very clearly observed in Rasetti's spectrogram. On the other hand the present theory offers a natural and convincing explanation of Rassetti's results, as has been shown by Dr. R. S. Krishnan in his report. The spectrogram and microphotometer record alike show the nine distinct frequencies required by the new dynamics of crystal lattices, quite clearly resolved from each other.

* * *

The success of the new crystal dynamics in offering a simple and natural explanation of a great body of spectroscopic facts shows that it rests on sound foundations. Various subsidiary issues, however, arise which require to be investigated in detail. One of these is the question, are there possible modes of vibration in which the space-units of the repeating pattern contain larger numbers of lattice cells than the eight indicated by the theory? Such a possibility was envisaged by me in a paper published in the *Proceedings* of the Academy two years ago. It is readily seen, however, that all modes of vibration in which equivalent atoms have the same amplitude of vibration are included in the theory already indicated. On the other hand, if the amplitudes are different, and the vibration pattern is on a larger scale, its modes and frequencies should be capable of being described, at least as a rough approximation, by the ordinary ideas of the elastic solid theory. Hence, we are justified in ignoring all such possibilities in a treatment of the vibration problem on a purely atomistic basis. That we have to exclude the three degrees of freedom of translation of the whole group of atoms in our enumeration of their possible modes of vibration is, however, a clear indication that there are other possible modes of vibration of the crystal lattice. It is *a priori* evident that these would be of lower frequencies and would closely resemble elastic vibrations of very small wave-lengths. The investigation of such modes of vibration is not without importance when we seek to apply the ideas of the new crystal dynamics to various problems, especially the calculation of the specific heats of the simplest types of crystal at the lowest temperatures.

* * *

The basis of our discussion so far is the classical mechanics, coupled with the idea that in considering the modes of atomic vibration in the interior of a crystal of macroscopic size, the conditions at the external boundary of the crystal are irrelevant. The agreement of the results of the theory with the experimental facts shows that such disregard of the boundary conditions at the surface of the crystal is justified. It indicates also that the various possible atomic states within a crystal are to be described in terms of space-units which are either the lattice spacings of the crystal, or integral multiples thereof and not in terms of sub-multiples of an arbitrarily assumed external dimension of the solid. We are naturally led to ask, should not similar ideas be extended to other aspects of the subject of crystal physics, including especially the theory of the electronic constitution of solids? The discussion which has been organised on this subject, and of which Professor K. S. Krishnan is the opener, may perhaps help to clarify the position of the latter problem and point the way to new and significant advances in our fundamental knowledge of the crystalline state of matter.

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SUPPLEMENT: THE FUNDAMENTALS OF CRYSTAL PHYSICS BY SIR C. V. RAMAN

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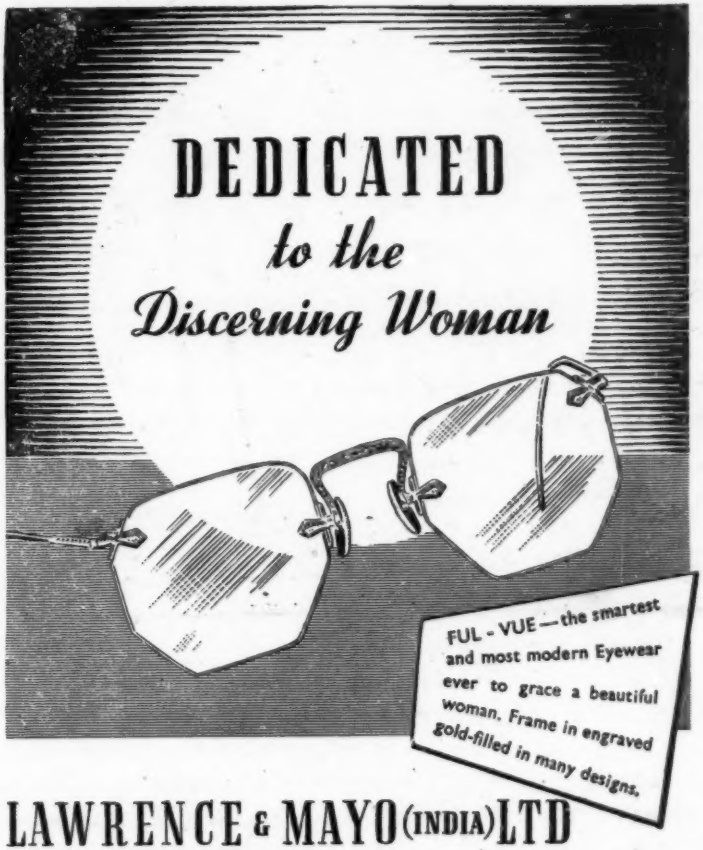
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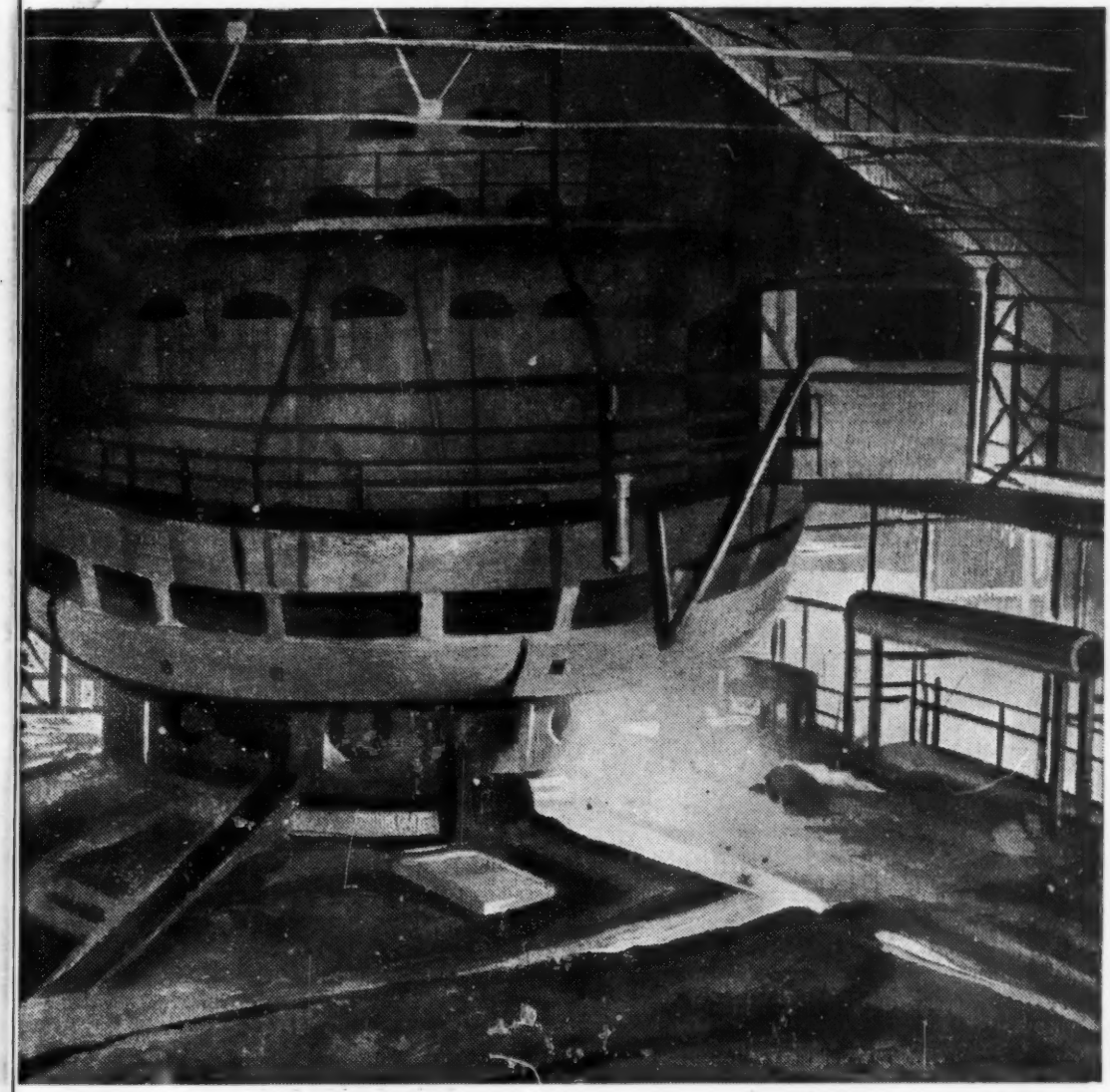

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